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TEXTURE AND MINERALOGY
OF OREGON BEACH SAND

by

RODNEY H. MCKAY

B.Sc. University of Oregon, 1960

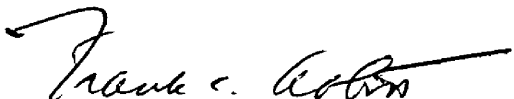
Presented in partial fulfillment of the requirements for the degree of
Master of Science

MONTANA STATE UNIVERSITY

1962

Approved by:


Chairman, Board of Examiners


Dean, Graduate School

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TEXTURE AND MINERALOGY
OF OREGON BEACH SAND

Rodney H. McKay

ABSTRACT

Beach sand along the northern Oregon coast can be differentiated texturally and mineralogically from beach sand along the southern Oregon coast. The boundary is at approximately Cape Blanco. North of Cape Blanco the beach sand is fine-grained, very well sorted, subangular, positively skewed, leptokurtic to mesokurtic and mineralogically impure arkose. Beach sand south of Cape Blanco is medium to coarse grained, subangular to subround, moderately sorted, negatively skewed, platykurtic to mesokurtic and mineralogically feldspathic graywacke. Northern beach sand is derived from the Tertiary sedimentary rocks and Quaternary sands of the Coast Range Mountains and is therefore second or third cycle. Southern beach sand is derived from the Mesozoic sedimentary, metasedimentary, and igneous rocks of the Klamath Mountains and is therefore first cycle.

There is a textural and mineralogic transition zone between northern and southern beach sand. The transition zone lies south of the lithologic boundary between Tertiary and Mesozoic rocks because the net direction of littoral drift is southward.

Beach and dune sands were differentiated by analysis of cumulative curves, and coplotting and standard deviation of statistical parameters.

Quartz petrology of Tertiary and Mesozoic sandstones and beach sand indicates that the Mesozoic rocks of the Klamath Mountains were not a major source for the Tertiary sedimentary rocks of the Coast Range Mountains. Feldspar petrology substantiates this conclusion. The fresh angular condition of feldspar in the sand shows that in regions of high relief feldspar is preserved even though a warm humid climate prevails.

An unstable suite of detrital heavy minerals is present in both northern and southern beach sand.

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INTRODUCTION

The Oregon coast offers an area to study beach sand where two different sediment sources lie in close proximity. One source is the Coast Range Mountains which are composed of Tertiary sedimentary and volcanic rocks. These mountains form approximately the northern two thirds of the coastal area. The other source is the Klamath Mountains which are made up of Mesozoic sedimentary, metasedimentary, igneous and metamorphic rocks. These mountains form approximately the southern third of the coastal area. The two sources are reflected texturally as well as mineralogically in the adjacent beaches. The textural and mineralogic boundary between northern and southern beach sands occurs at approximately Cape Blanco. (Fig. 1). Beaches along the northern coast are generally long and separated by large headlands of volcanic rock. The northern beach sand is fine-grained, texturally mature impure arkose (Folk, 1961, p. 111). Southern beaches are generally shorter and separated by headlands of metasedimentary rock. Southern beach sand is medium to coarse grained, texturally submature feldspathic graywacke.

Acknowledgments

I am grateful to Mr. D. Winston for his critical reading of the manuscript and also for his valuable suggestions. The comments and criticisms of Doctors F. S. Honkala, J. P. Wehrenberg and T. J. Nimlos have greatly aided in the completion of the work.

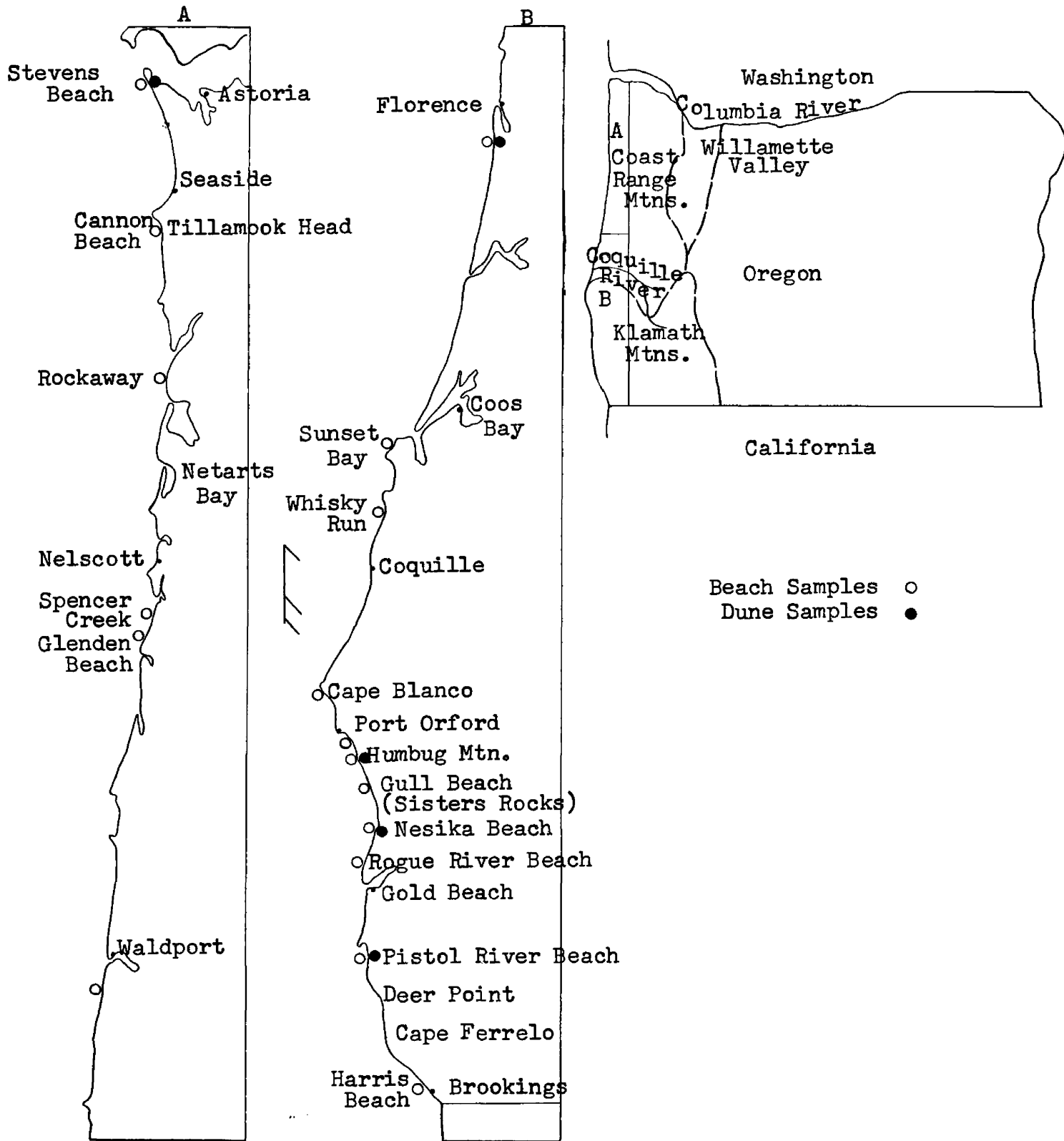


Figure 1. Index Map

Field and Laboratory Procedures

Samples were collected from eighteen beaches along the Oregon coast ranging from Stevens Beach on the north to Harris Beach on the south. (Fig. 1). Five dune areas and four Quaternary terrace deposits were also sampled. All beach samples were collected from the intertidal zone at low tide. Samples six to eight inches deep were taken from traverses normal to the strand line at approximately ten-foot intervals (Fig. 2). Samples from each traverse were combined to form a channel sample that is characteristic of the sand across the intertidal zone. Three or four channel samples, at 750-foot intervals along the beach were taken from six of the seven southern beaches. The three or four channel samples from each southern beach will hereafter be referred to as a set, and channel samples in each set are numbered beginning at the southernmost sample. One channel sample was taken from each northern

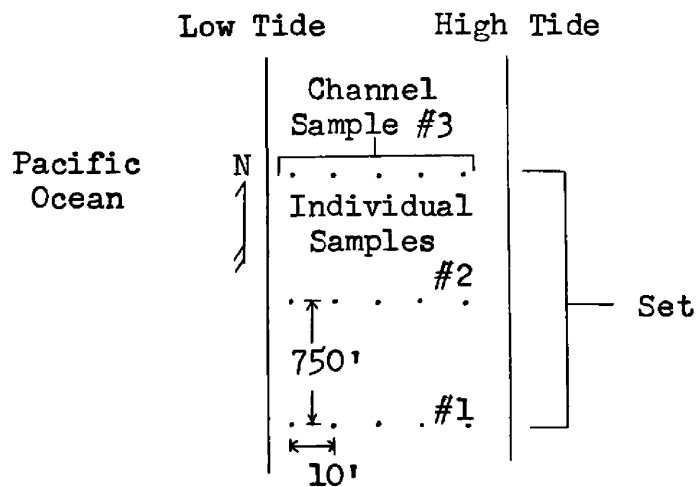


Figure 2. Method of locating beach samples

beach. Dunes were sampled on leeward and windward sides as well as representatively. The top two to six inches of sand was taken for each sample. Quaternary outcrops were first scraped to insure a fresh surface and then sampled to the depth of an inch or two.

Size analyses were made on all samples with a Ro-Tap machine using an interval of .5 ϕ over a total range of -.5 ϕ to 4 ϕ . Results from each analysis were plotted on probability paper and statistical parameters were computed. Size fractions from 0 ϕ to 2.5 ϕ were separately retained from the southernmost, or first, sample of each of the six southern sets. Each of these phi-size samples was impregnated with Castolite liquid casting plastic and thin-sections were prepared. The 2.5 ϕ size fraction from each additional southern sample was impregnated and sectioned. Unsieved aggregate comparison sections were prepared from each southern sample and from five beach samples along the north coast. One hundred grains were counted in sections of each phi-size and three hundred grains were counted in each aggregate section.

Thin sections of rocks in the headlands adjoining southern beaches and Tertiary sandstones close to the Klamath Mountains were analysed.

Heavy mineral separations were done on the 3 ϕ unit of the first sample from each of the southern beaches and all of the northern beach samples. Major heavy mineral species were identified but grain counts were not attempted.

Explanation of Statistical Parameters

Statistical parameters used in this thesis are taken from Folk

(1961, pp. 44-47) and from Folk and Ward (1957).

Graphic Mean (M_z)

Overall size is shown by this parameter. The formula used is $M_z = (\phi_{16} + \phi_{50} + \phi_{84})/3$ where ϕ_{16} represents the ϕ size corresponding to the 16th percentile. Because three points on the cumulative curve are used in computing graphic mean, it gives a good indication of overall size.

Inclusive Graphic Standard Deviation (O_I)

Sorting of the sand is computed by this statistical parameter. Because the formula, $O_I = (\phi_{84} + \phi_{16})/4 + (\phi_{95} + \phi_5)/3$, includes 90% of the size distribution, it gives a very good measure of overall sorting.

Inclusive Graphic Skewness (Sk_I)

Skewness measurements indicate the presence or absence of material at the ends of the size distribution, in other words, whether or not the sample has a fine or coarse "tail". Coarse "tails" give negative skewness and fine "tails" give positive skewness. Symmetrical curves have skewness values at or near 0. Skewness is given by the formula:

$$\frac{(\phi_{16} + \phi_{84} - 2 \phi_{50})/2}{(\phi_{84} - \phi_{16}) + (\phi_5 + \phi_{95} - 2 \phi_{50})/2} \frac{(\phi_{95} - \phi_5)}{(\phi_{84} - \phi_{16})}$$

Kurtosis (K_G)

In normal probability curves the distance on the abscissa between the ϕ_5 and ϕ_{95} points is 2.44 times the distance between the ϕ_{25} and ϕ_{75} points. Kurtosis is a measure of the deviation

from this ideal situation. If a curve is excessively peaked, then the spread between ϕ_{25} and ϕ_{75} will be less than normal and the kurtosis value will be greater than 1. Normal curves have kurtosis equal to 1. If a curve is broadened or flattened then the kurtosis value will be less than 1. The formula $K_G = (\phi_{95} - \phi_5) / 2.44 (\phi_{75} - \phi_{25})$ give kurtosis values. Folk and Ward (1957) used the term, $K_G = K_G / K_G + 1$, the normalized kurtosis function for statistical manipulation of kurtosis values. This normalized function is used here.

General Geology of Western Oregon

In describing the general geology of western Oregon, only those formations which crop out within a mile of the coast will be discussed. Petrographic descriptions of the Tertiary, Tyee and Coaledo sandstones and the Mesozoic Dothan, Days Creek and Riddle Formations are included in the section on petrography. All information in this section has been taken from Baldwin (1959) and from the Geologic Map of Western Oregon (1961).

Coast Range

Tertiary sandstones, siltstones and volcanic rocks comprise most of the Coast Range Mountains, which form a broad anticlinorium. They extend from the Columbia River on the north to the middle fork of the Coquille River on the south and from the Pacific Ocean on the west to the Willamette Valley on the east (Fig. 1). In general the sediments are tuffaceous, micaceous and feldspathic sandstones and volcanic basalts. Large headlands along the northern coast are composed of basalts. Marine terraces are well developed in places. A narrow

coastal plain separates the coast from the mountains. Dunes are best developed on the plains from the mouth of the Columbia River to Seaside and from Florence to Coos Bay.

It may be said that the backbone of the Coast Range is the Tyee sandstone of middle Eocene age. This formation is composed of rhythmically bedded micaceous sandstone and siltstone. Baldwin (1959, p. 23) states that individual rhythmites thicken and become sandier to the south, which indicates a source to the south. Plant remains are disseminated throughout the Tyee suggesting a brackish or near shore environment.

The upper Eocene Coaledo sandstone crops out in prominent cliffs south of Coos Bay. For the most part it is a medium to coarse grained sandstone with intercolated finer grained beds. Most of the coal found in the Coast Range occurs in this formation. Baldwin (1959, p. 23) found large amounts of basaltic rock fragments in the formation.

Middle Miocene sediments known as the Astoria formation crop out along the coast from Tillamook Head to Netarts Bay. They consist of fine to medium grained feldspathic and tuffaceous sandstone. In places the formation is conglomeratic and crossbedded.

Klamath Mountains

South of the Coast Range in southwestern Oregon and northwestern California lie the Klamath Mountains. This is a region of sedimentary, metasedimentary, volcanic, metavolcanic and intrusive igneous rocks. The pre-Tertiary strata are folded, faulted and in places intruded by silicic to ultrabasic igneous rocks. A narrow coastal plain separates the ocean from the mountains. Late Cenozoic uplift caused the rivers

to cut deep canyons into the Mesozoic and Paleozoic strata.

The late Jurassic Dothan Formation crops out along the coast in the southwestern corner of Oregon. It is predominantly a medium-grained well-indurated muddy sandstone and siltstone which locally displays a slaty cleavage. Intercolated volcanic rocks, conglomerate and chert are also present.

From Cape Ferrelo north to approximately Deer Point and from Gold Beach north to Sisters Rocks the late Jurassic Riddle Formation crops out along the coast. It is composed of siltstone with minor thin beds of well-indurated carbonaceous sandstone. Chert pebble conglomerate and limestone beds are also present.

South of Port Orford to Sisters Rocks the early Cretaceous Days Creek Formation extends to the ocean. Interbedded, well-indurated, fine-grained sandstone and sandy siltstone predominate. Subordinate limestone lenses are also present.

TEXTURES

Introduction

Beaches along the southern Oregon coast consist of medium to coarse grained, subangular to subround sand, that is moderately sorted, negatively skewed and platykurtic to mesokurtic (Table 1). From approximately Cape Blanco north to the Columbia River, the northern beaches are composed of fine grained, very well sorted, subangular sand with slight to moderate positive skewness and mesokurtism to leptokurtism (Table 1).

Texturally, southern beach sands are submature (Folk, 1961, p. 100). That is, they contain no clay size grains and are only moderately sorted. Northern beach sands are texturally mature because they contain no clay size grains, are very well sorted but are still subangular.

Analysis of Cumulative Curves

Cumulative curves plotted on probability paper give a very accurate representation of the size distribution of the sand. If it is assumed that the sorting effect of the beach environment tends to produce a normally distributed sediment, then the cumulative curves of beach sand will be straight lines. Therefore, changes in the slope of the cumulative curves indicate abnormally low or high amounts of sand at those sizes associated with the changes in slope. Figure 3 illustrates where breaks in slope occur and whether the slope increases or

Southern Beaches	$M_Z \phi$	$\sigma_1 \phi$	Sk_1	K'_G
Harris Beach	1.90	.52	-.24	.53
Pistol River Beach	1.32	.84	-.36	.43
Rogue River Beach	1.44	.85	-.22	.48
Nesika Beach	.93	.71	-.15	.50
Gull Beach	1.09	.75	-.16	.46
Humbug Mountain	1.01	.88	-.29	.45
Port Orford	1.47	.50	-.01	.49
Cape Blanco	2.31	.32	.00	.53
Southern Dunes				
Humbug Mountain	1.67	.33	-.12	.54
Nesika Beach	1.52	.41	.00	.50
Pistol River Beach	2.03	.37	.02	.51
Northern Beaches				
Whisky Run	2.25	.29	.02	.56
Florence	1.69	.33	-.04	.55
Waldport	2.36	.32	.12	.60
Spencer Creek	1.99	.26	.08	.50
Glenden Beach	1.53	.35	-.16	.51
Rockaway	1.97	.21	.19	.51
Cannon Beach	2.28	.22	.13	.55
Stevens Beach	2.22	.32	.06	.53
Columbia River Beach	2.08	.41	.16	.53
Northern Dunes				
Florence	2.21	.27	.05	.53
Stevens Beach	2.54	.34	.13	.49

Table 1. Averages of statistical parameters from beaches and dunes.

Location	$M_Z \phi$	$\sigma_1 \phi$	Sk_1	K'_G
Humbug Mountain (South)	1.01	.88	-.29	.45
Port Orford	1.47	.50	-.01	.49
Cape Blanco	2.31	.32	.00	.53
Whisky Run (north)	2.25	.29	.02	.56

Table 2. Statistical parameters across the transition zone between southern and northern beach sands.

decreases. Increases in slope indicate additions to sizes involved in the slope increase or subtractions from other sizes. Decreases in slope indicate subtractions from sizes involved in the slope decrease or additions to other sizes. Figure 3 shows that in the curves of southern beach sand, increases in slope commonly occur at $-.5\phi$ and 0ϕ . Analysis of southern dune sand shows that 1ϕ and 1.5ϕ sizes are not being actively transported from the beaches to the dunes. Therefore, $-.5\phi$ and 0ϕ sizes appear to be accumulating at abnormally high rates on the beaches. In general there is a flattening of southern beach sand curves from about $.5\phi$ to 1.5 or 2ϕ indicating that these sizes have normal distribution. From about 1.5 to 2ϕ to 2.5ϕ the slope of southern beach sand curves increases, indicating that there is sand of these sizes being added to the normally distributed beach sand. From this analysis it is apparent that southern beach sand is bimodal. The coarser mode occurs at $-.5$ to 0ϕ and the more prominent finer mode occurs at 1.5 to 2.5ϕ . Weathering and erosion of rocks in the Klamath Mountains produces the coarse mode. Southward migration of northern beach sand, in the medium size range, added to the normally distributed southern beach sand of these sizes results in the finer mode. Northern beach and dune sands show normal size distribution.

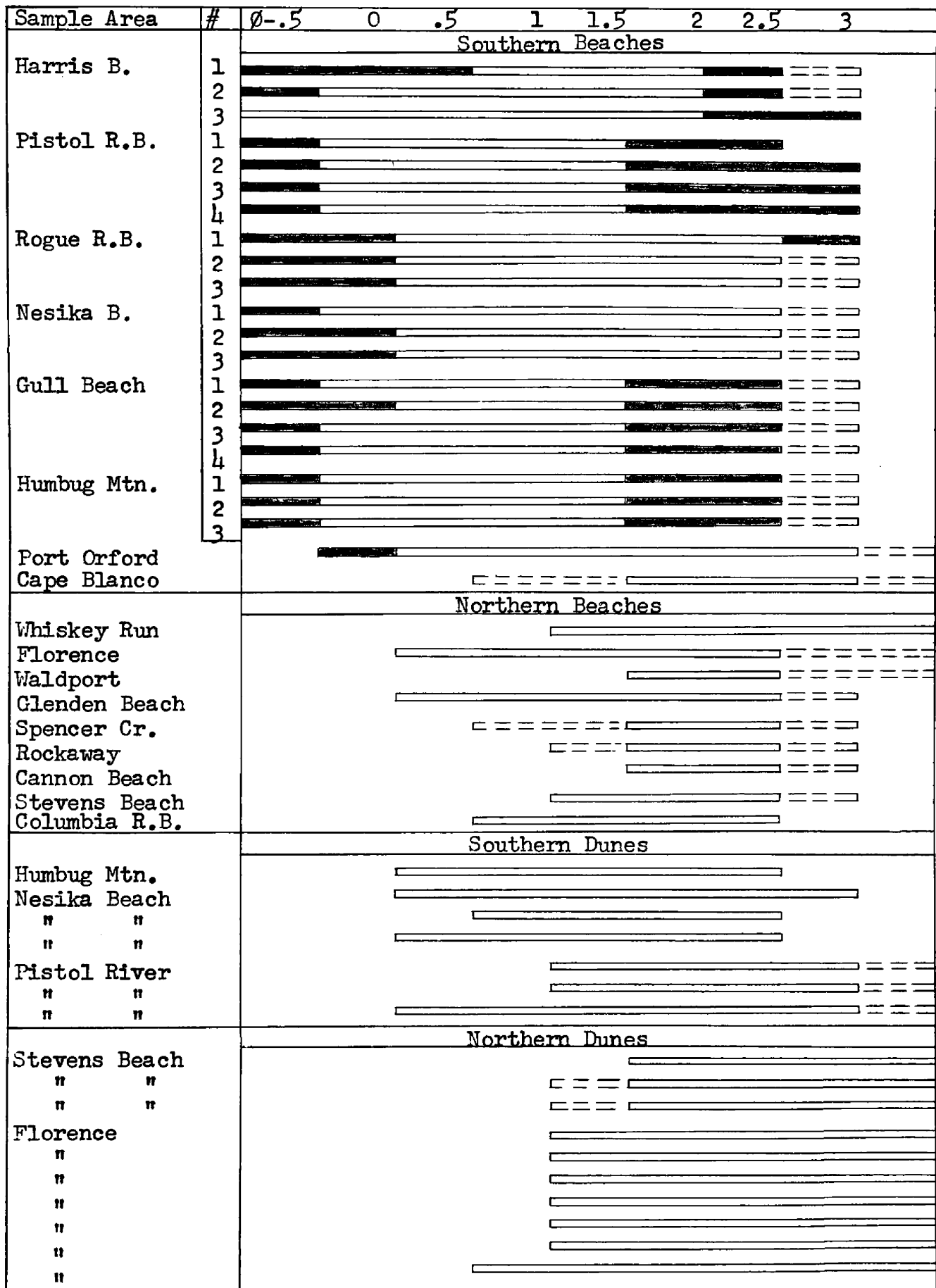


Figure 3. Breaks in slope of cumulative curves.
 Increase Decrease Normal

Statistical Parameters

The textural differences between northern and southern beach sand result in very different statistical parameters in the two areas (Table 1). These differences are pointed out by the differences in mean size, graphic standard deviation, skewness and kurtosis.

Differences in mean size and standard deviation can be related directly to the source areas. Along the northern Oregon coast, north of Cape Blanco, relatively unindurated Tertiary rocks and Quaternary sediments on the terraces are easily eroded and readily break down to the original sedimentary grains. Therefore, northern beach sands are at least second cycle. This explains the finer grained and better sorted features of the northern beach sand. South of Cape Blanco the well indurated Mesozoic sedimentary, metasedimentary and igneous rocks of the Klamath Mountains weather to produce consolidated rock fragments. These first cycle grains produce coarser and more poorly sorted beach sand than do the second and third cycle grains of the northern beaches. This explanation is supported by the differences in mineralogy which will be discussed in a later section.

Differences in skewness between northern and southern beach sand are marked. Southern beach sand displays marked negative skewness, while northern beach sand is slightly to moderately positively skewed. Folk and Mason (1958, p. 223) proposed that skewness results from additions to or subtractions from an originally unimodal sediment. These additions and subtractions are made at the coarser and finer ends of the size distribution. Additions come from secondary sources

coarser or finer than the main body of the sediment. Subtractions result from changes in hydrolic conditions at the site of deposition or removal of the finer sizes by wind.

It may be possible to explain the positive skewness of northern beach sand by Folk and Mason's theory. The removal of fine sand from the beach by wind would tend to produce a negative skewness in the beach sand. However, northern beach sands are positively skewed. Contamination of the beach sand by the easily eroded terrace deposits could not produce a positive skewness because samples of the terrace sand indicate it is slightly coarser than the beach sand. Changes in hydrolic conditions which would result in the removal of the coarser sand would also cause the removal of the finer sand. One possibility is that skewness results from changes in hydrolic conditions which promoted the deposition of finer sand on the beach. Another possibility is that the source of supply contains a considerable amount of fine sand which is eventually deposited on the beach in large enough quantities to produce positive skewness even though wind erosion of the beaches tends to produce negative skewness. This appears to be the most reasonable explanation.

Southern beach sand displays marked negative skewness, not for the reasons suggested by Folk and Mason, but rather because the southern beach sand is bimodal. Graphic differentiation of cumulative curves (Crumbein and Pettijohn, 1938, p. 191) and analysis of cumulative curves drawn on probability paper show that two modes are present, one at about 0ϕ and another at about 2ϕ . In almost all samples the greater mode is the finer one and for this reason the sand is

negatively skewed. Wind erosion of southern beaches also tends to emphasize negative skewness in the beach sand.

Kurtosis values for northern beach sand are all above .50 while most of kurtosis values from southern beach sand are below .50. Thus southern beach sand is platykurtic to leptokurtic. Platykurtism in southern beach sand is the result of the bimodality of the sand which in turn is related to the fact that southern beach sand is partially first cycle. Mesokurtism and leptokurtism in the northern beach sand reflects the good sorting and unimodality of the sand which are related to the fact that northern beach sand is second and third cycle. Therefore, the kurtosis of northern and southern beach sand is directly related to the source areas.

Transition Zone

Northern and southern beach sands are separated by a zone of transition which lies slightly to the south of the lithologic contact between Tertiary and Mesozoic rocks. It has been pointed out earlier in this section that southward migration of northern sand results in a mode being developed at 1.5 to 2.5 ϕ in southern beach sand. One line of evidence to support the idea that the fine mode does actually result from addition of northern sand lies in the net direction of littoral drift. Cooper (1958, p. 20) states that the general regime of fairly constant, low velocity winds from the north or northwest in summer should cause a net southward littoral drift. This is in spite of the intermittent high velocity winter winds from the south or southwest. If this is true, then cumulative curves and statistical parameters across the zone

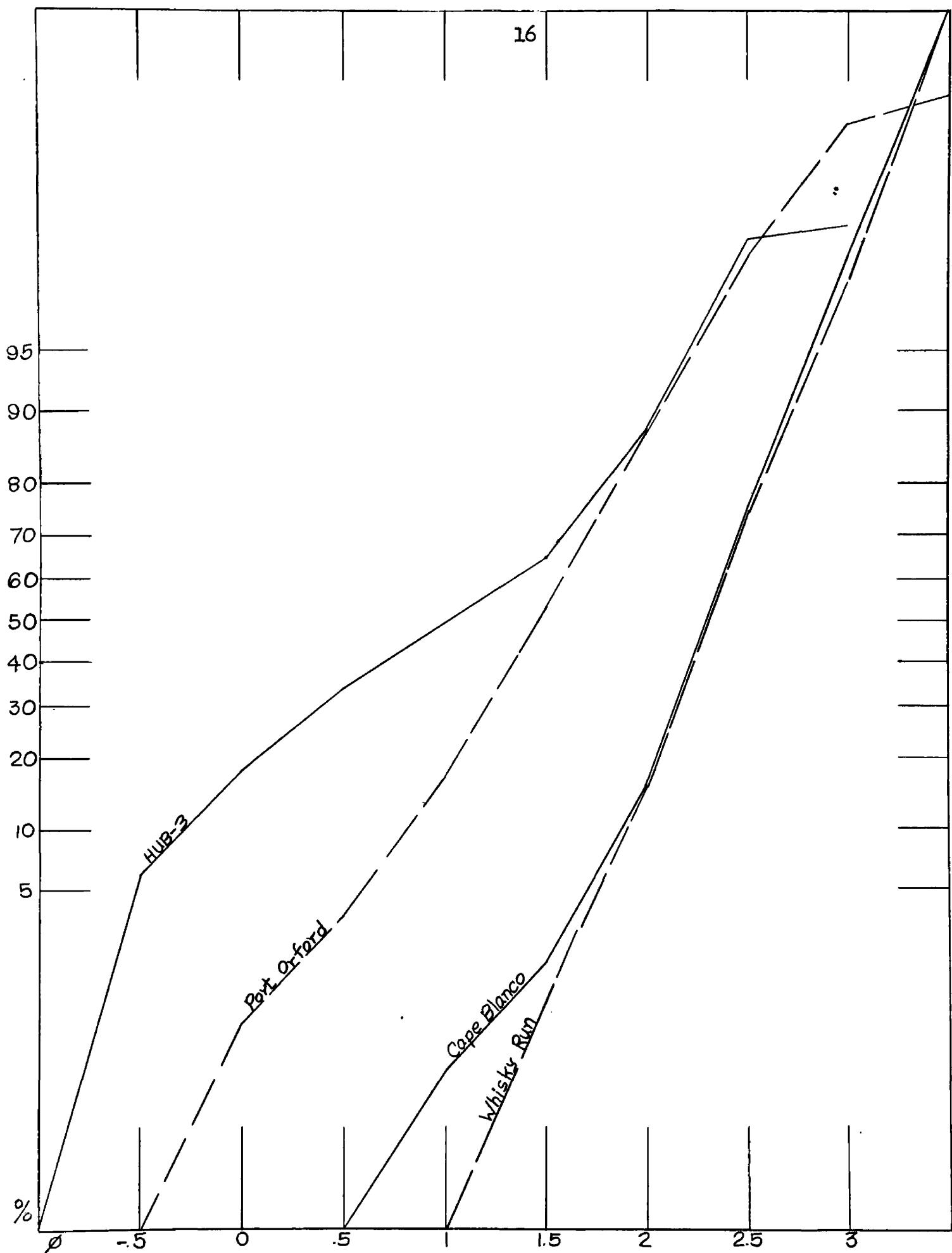


Figure 4. Cumulative curves across the transition zone.

of transition should show gradation from northern to southern beach sand. This transition should be south of the lithologic contact between Tertiary and Mesozoic rocks. Figure 4 shows cumulative curves across the transition zone from Humbug Mountain on the south to Whisky Run on the north. Table 2 illustrates statistical parameters across the zone. Samples from Port Orford and Cape Blanco, which are in the region of southern beach sand, show textural transition between northern and southern beach sands. Mineralogically, beach sands from Cape Blanco are transitional. This will be discussed in the section on mineralogy.

Differentiation of Beach and Dune Sand

Cumulative curves

An aid in differentiating beach from dune sand may be provided by cumulative curves plotted on probability paper. Figure 3 illustrates the breaks in slope of cumulative curves and shows whether there is an increase, decrease or whether the distribution is normal. Southern beach sand is obviously bimodal. Northern beach sand displays more normal size distribution but there are irregularities particularly in the finer sizes. Dune sand from both northern and southern areas shows good normal distribution.

One characteristic of beach sand appears to be the abnormal decrease in amount of sand at the fine end of the size distribution. Both northern and southern beach sand displays this feature, while dunes generally do not. A combination of factors is responsible for this difference. Under the rigorous environment of the beach only a small

amount of fine sand accumulates. Wind erosion of the beach removes some of this fine sand and deposits it in the dunes, thus emphasizing the low amount of fine material in the beach sand. Fine sizes have a more normal distribution in dune sand because of the critical sorting power of the wind. The abnormal decrease in fine sand on the beaches and the more normal distribution of this fine sand in the dunes is the result of erosional and depositional processes of the particular environment and is therefore an aid in differentiating these environments.

Coplotting of statistical parameters

Plotting of one size parameter against another was used by Folk and Mason (1958) to differentiate beach, dune and aeolian flat environments. They concluded that the plot of skewness versus kurtosis gave the best separation of environments. Scatter plots of the six possible combinations are shown in Figures 5 and 6.

By coplotting any two parameters, northern and southern beach sands can be differentiated. Southern dune sand and southern beach sand are also easily separated by coplotting any two parameters. However, northern dunes and northern beaches are not differentiable in any of the size plots. The mode of northern beaches is strong and very pronounced and as a result the derived dunes are unimodal. Apparently, wind erosion of the northern beach sand and deposition of this sand in northern dunes transfers the textural features of the beach sand to the dune sand. Therefore, statistical parameters of northern beach and dune sand are very similar and coplotting of these parameters does not give good separation of beach and dune sand.

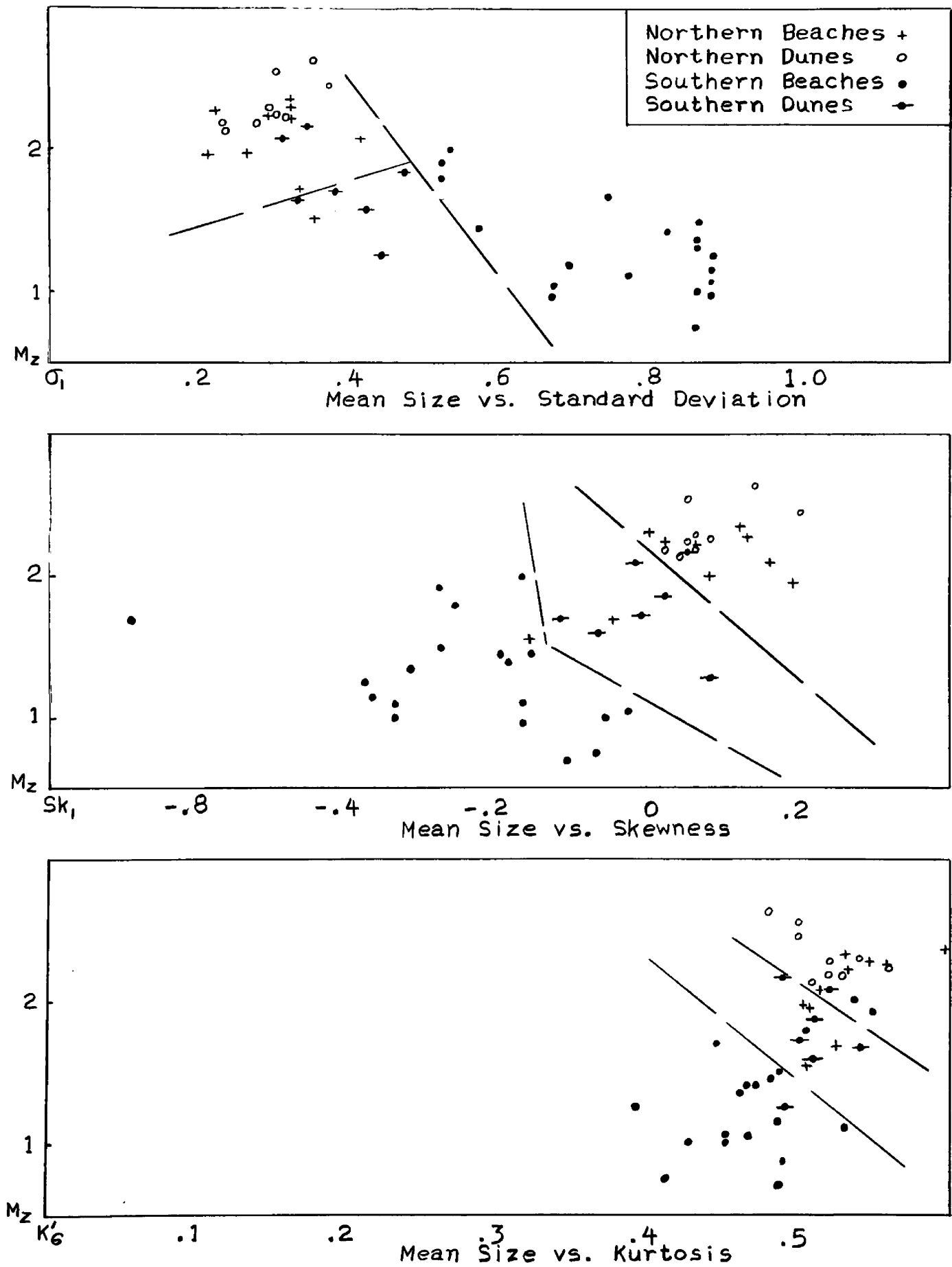


Figure 5. Coplots of statistical parameters of northern and southern beaches and dunes.

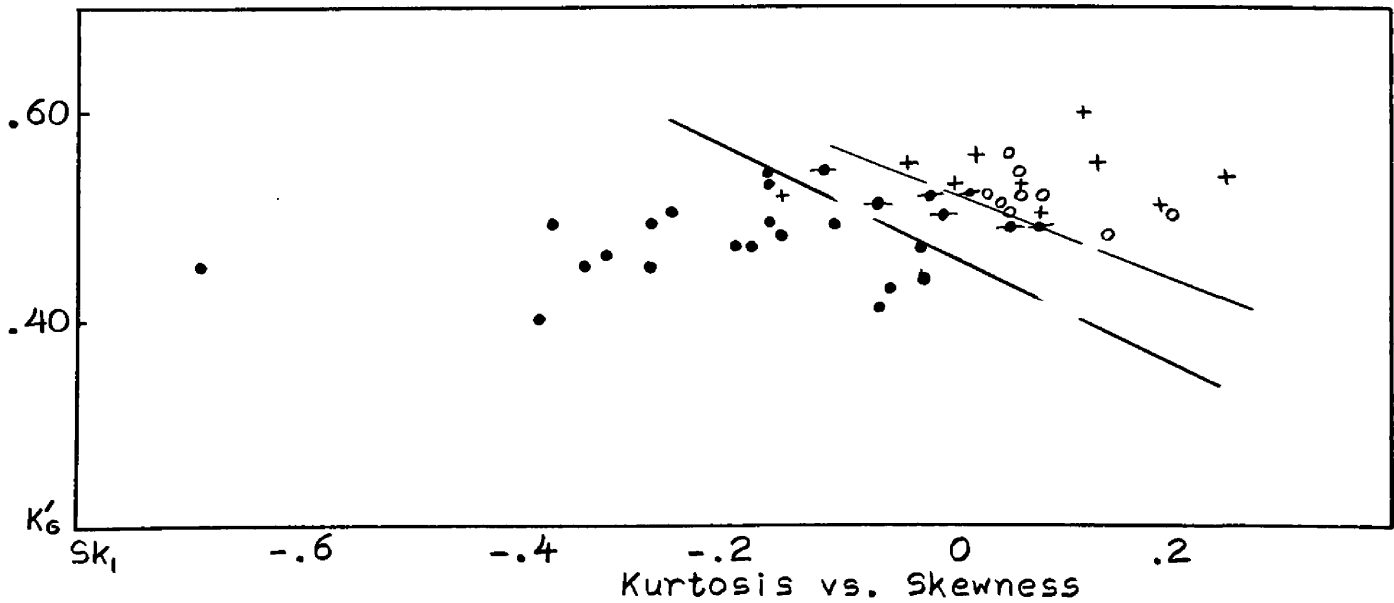
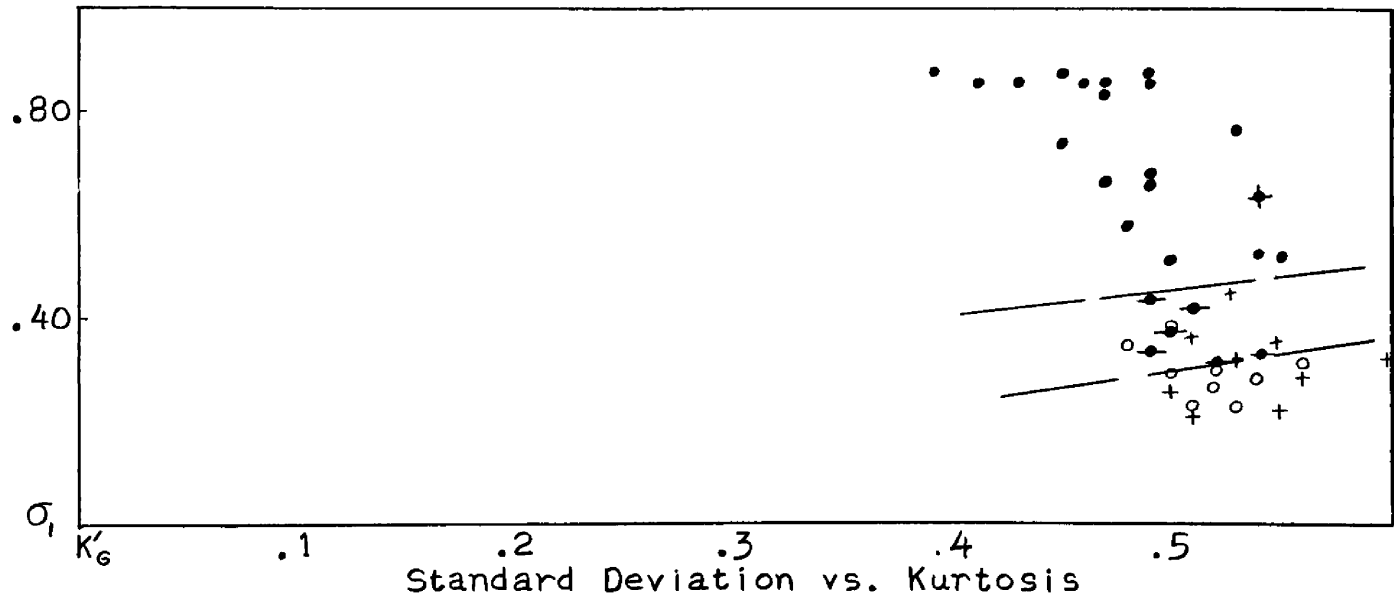
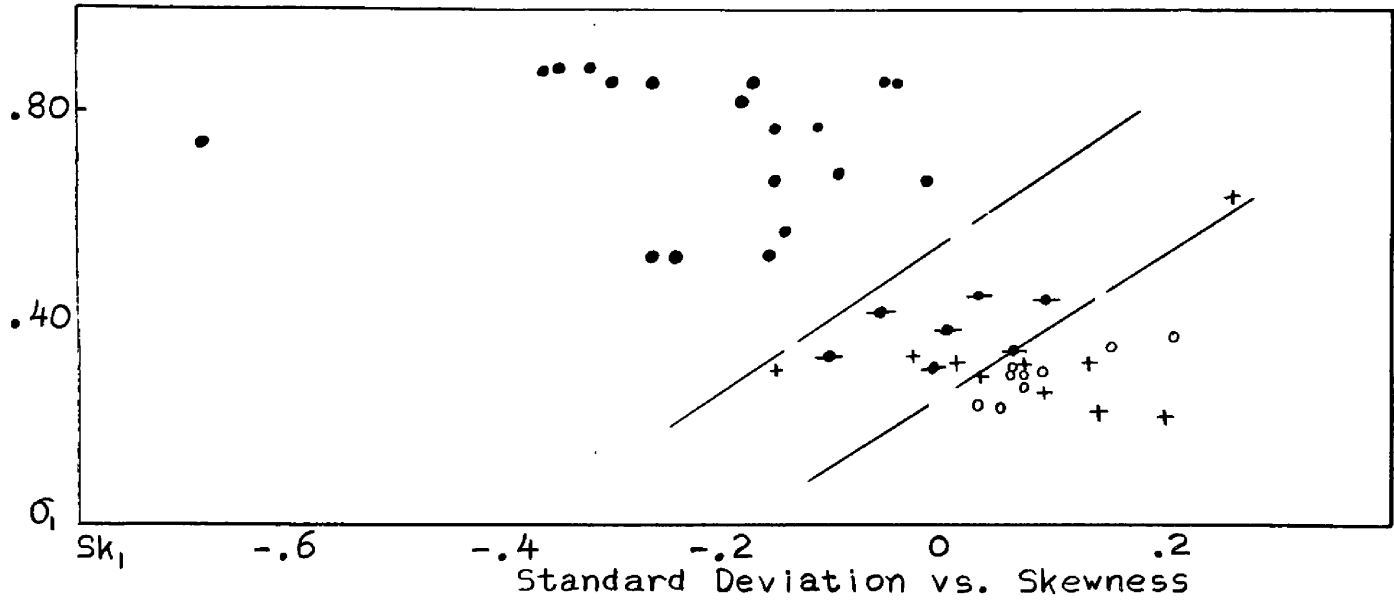


Figure 6. Coplots of statistical parameters of northern and southern beaches and dunes.

Standard deviation of statistical parameters

Some indication as to environment and source material may be deduced from the standard deviation of statistical parameters. Figure 7 illustrates the standard deviation of each parameter from the four areas of study.

Southern beaches show the lowest standard deviation with respect to mean size. This fact is anomalous because southern beach sand is texturally submature and displays the highest variance in all other parameters. This peculiarity remains unexplained. Mean size standard deviation values for the unimodal dune and northern beach samples shows the variance in modes from sample to sample. The smaller variance in mean size of the northern dunes reflects the critical sorting power of the wind and emphasizes the unimodality of the source. However, southern dune samples show the highest standard deviation with respect to mean size. Southern dune sand does not reflect the bimodality of southern beach sand but rather is unimodal as a result of wind erosion of the southern beaches. The wind erodes a wide range of sand sizes from southern beaches and deposits all sizes in the dunes, thus causing the dunes to have a large variance in mean size from place to place.

Standard deviation of graphic standard deviation, a measure of sorting, differentiates beach sand from dune sand. Wind erosion of beach sand and deposition of this sand in dunes produces a better sorted dune sand with low variance in sorting values. Northern dune sand has a mean sorting value very similar to northern beach sand but has a smaller standard deviation. This is a reflection of the critical

sorting power of the wind. The sorting effect of the wind with respect to southern beach and dune sand is marked because the beach sand deviates so markedly from normal distribution.

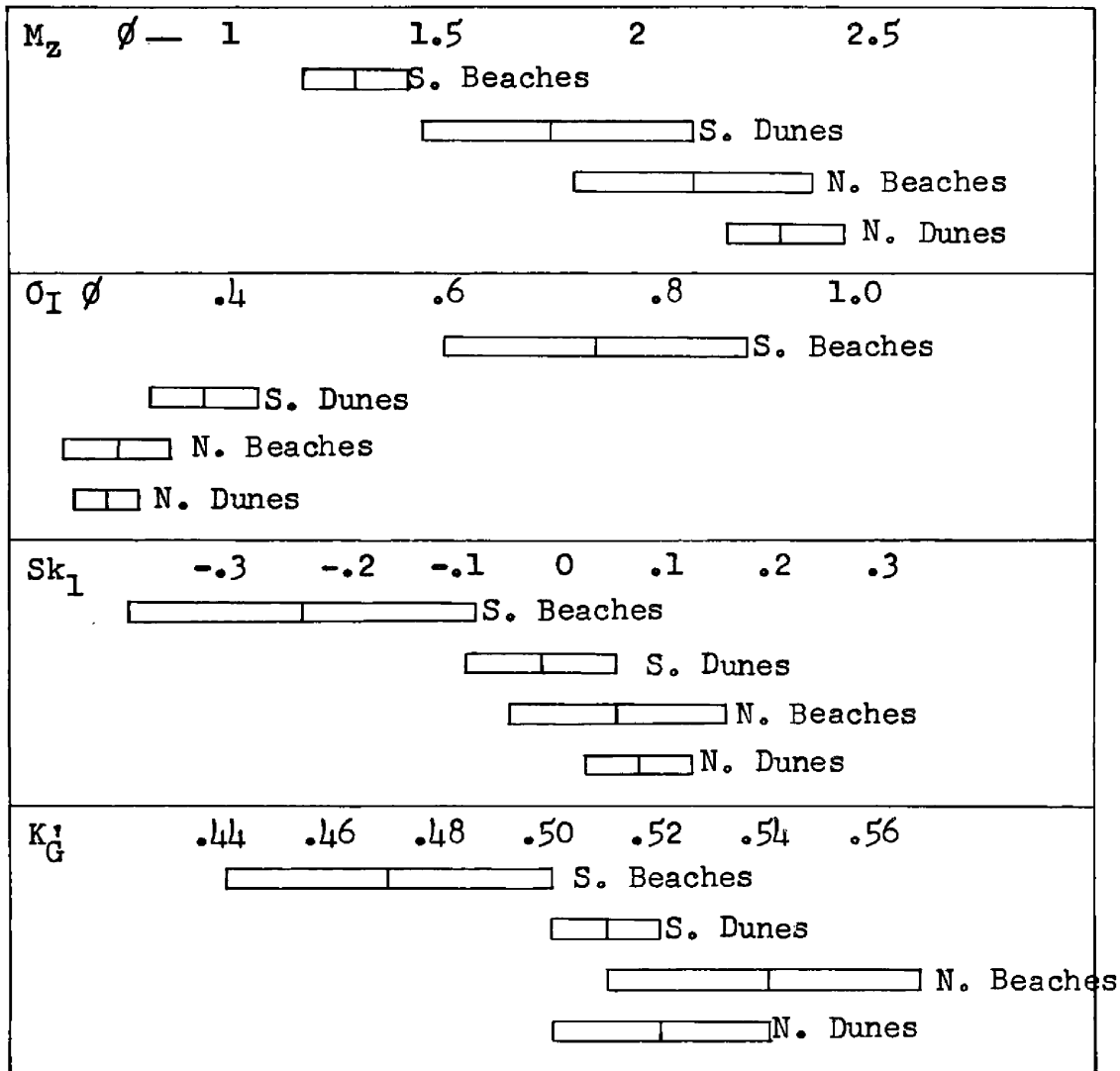


Figure 7. Standard deviation of statistical parameters. One standard deviation plotted on either side of the arithmetic mean.

Standard deviation of southern beach skewness indicates the fluctuation in relative amount of the modes. That is, if the fine mode decreases a more negative skewness should result and vice versa.

Northern and southern dunes show a narrower standard deviation in skewness values than do northern and southern beaches. In both cases wind erosion of the beaches and deposition in the dunes leaves the coarser material on the beaches, thus skewness of dune sand is more normal.

Standard deviation of kurtosis values for southern beaches and dunes show essentially the same features as the other parameters. The wind leaves the coarser mode on the beach and produces a normally distributed dune sand. In the northern beach and dune sand, wind erosion seems to eliminate the leptokurtic character of the sand as it moves from the beach to the dune environment.

Conclusions based on averages

Some generalizations concerning the effect of wind erosion of beach sand and its eventual deposition in the dune environment can be made. Bimodality appears to be lost because of the sorting effect of the wind. There is a decrease in mean size from beach to dune environment. Narrower skewness limits exist in the dune environment. There is a tendency to eliminate negative skewness in the dune environment particularly if the source beach shows high negative skewness. Mesokurtism seems to be generally characteristic of the dune environment because the tendency of wind erosion of beaches appears to be to normalize the size distribution in the resulting dunes.

Specific beach-dune pairs

The foregoing conclusions are based on overall averages of statistical parameters. If they are valid then they should hold for

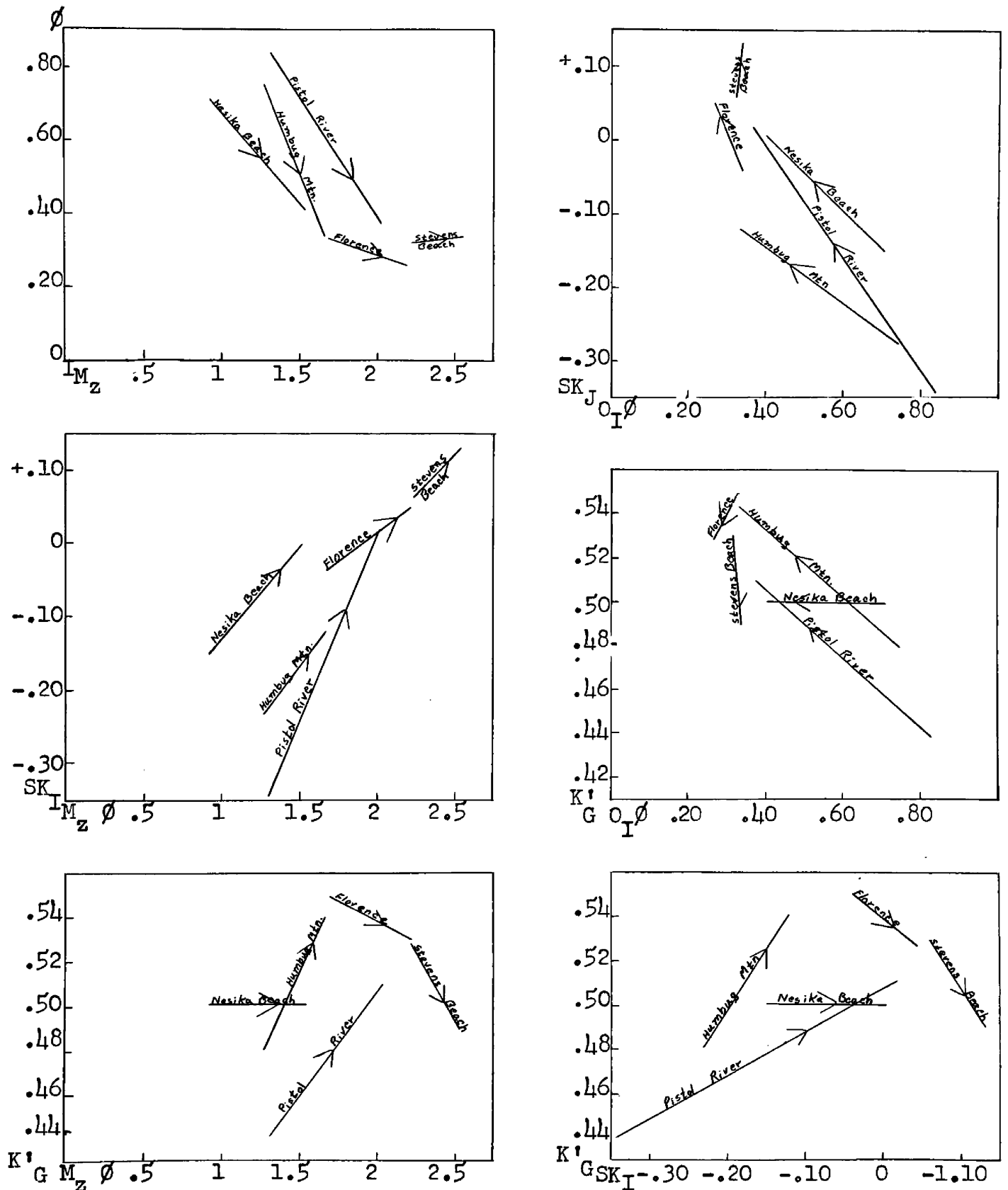


Figure 8. Coplots of averaged statistical parameters of beach-dune pairs. Arrows indicate direction from beach to dune.

specific cases. Figure 8 illustrates the change in each parameter when sand is blown from beach to dune in specific beach-dune pairs. In each case wind erosion of the beaches and deposition in the dunes results in a finer grained dune sand. As expected, comparisons of southern beaches and dunes show the greatest change from coarse to fine grains.

Graphic standard deviation values decrease from beach to dune sands everywhere but at Stevens Beach, where the dunes are stabilized by trees and grasses. As pointed out by Folk and Mason (1959, p. 225) fine grained sediments blown onto the dunes are probably trapped by the vegetation and decrease the effect of wind sorting. Sediments from the stabilized dunes are much finer grained than those of any other dunes and seem to validate the theory.

Skewness values show a positive trend from beach to dune, probably because finer material is concentrated in the dunes by the wind. There is a limit to the amount of fine material available for transport from beach to dune because of the rigorous beach environment.

The trend of kurtosis values seems to be toward mesokurtism. Southern beaches are platykurtic while southern dunes are mesokurtic. Northern beach-dune pairs show a trend from leptokurtism to mesokurtism from beach to dune. One might expect the wind to produce better sorting, emphasize the modes and cause the dune sand curves to become leptokurtic. This does not appear to happen perhaps because the distribution of sand on the beach, in the sizes which wind will transport, is more normal than the overall distribution of the beach sand. Kurtosis values recalculated from curves using beach sand of the same size range as dune sand are inconclusive. Perhaps the real answer is that

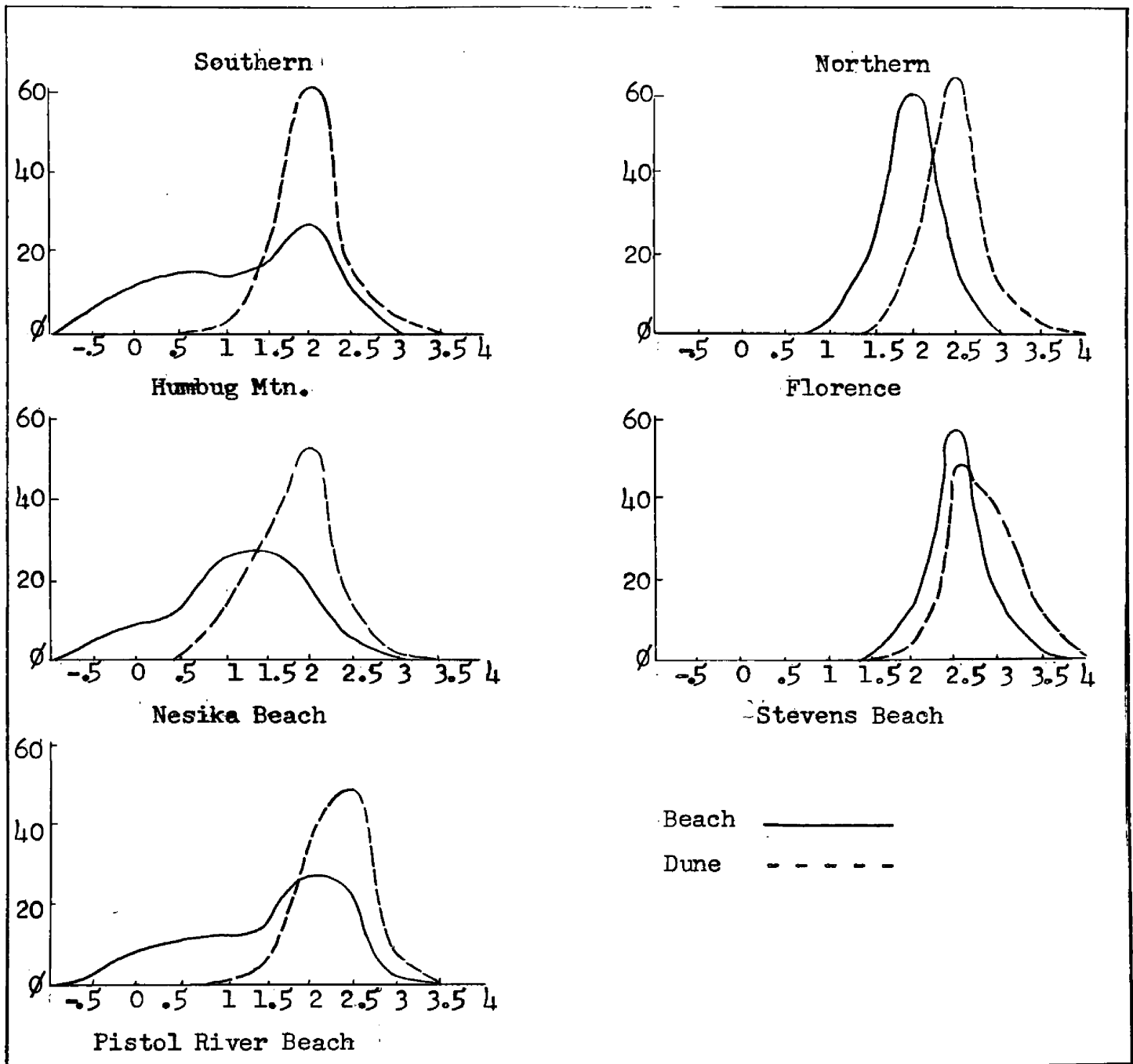


Figure 9. Frequency curves of beach-dune pairs.

the trend only appears to be toward mesokurtism. The three southern beach-dune pairs do display a trend toward mesokurtism in moving from beach to dune. However, the reason probably is not because of a general rule but rather because of availability of material. If enough sand

of 2.5 ϕ or 3 ϕ is present on the beaches, then platykurtism could result. This fact is explained by analyzing Figure 9 which represents smoothed frequency distribution curves of beach-dune pairs. Wherever there is 15 or 20% of the beach sand in the 2.5 ϕ size, a mode of this size is developed in dune sand even though a mode at 2 ϕ is present on the parent beach. In one case where there is 16% 3 ϕ material on the beach a secondary mode at 3 ϕ is developed in the dunes. In other words sizes smaller than about 1.5 ϕ are selectively transported from the beach in ratios inversely proportional to size and directly proportional availability. Therefore platykurtism, mesokurtism and leptokurtism are all possible if the proper proportions of proper sizes are present on the parent beach. Therefore, source as well as environment of deposition determine the size distribution of dune sands.

Conclusions Based on Textural Analysis

Textural differences between beach sand north and south of Cape Blanco are the result of different source areas. Northern beaches are texturally more mature because they are derived from the poorly-cemented Tertiary sedimentary rocks of the Coast Range Mountains and Quaternary deposits. Thus, they have been exposed to at least two or three cycles of erosion and deposition. Southern beach sands are coarser and texturally less mature because they have been derived from the highly indurated Mesozoic rocks of the Klamath Mountains. These rocks weather to produce a coarser beach sand which is predominantly first cycle.

Southern beach sands are bimodal. Erosion of Mesozoic rocks of the Klamath Mountains produces a mode at -.5 ϕ to 0 ϕ in southern beach

sands. Southward moving northern sand mixing with southern sand of 1.5 ϕ to 2.5 ϕ sizes creates a second mode in this size range. Platykurtism, poor sorting and marked negative skewness of southern beach sand are the result of the bimodality of the sand. Northern sands are fine and distinctly unimodal. They are very well sorted, leptokurtic and positively skewed.

A textural transition zone between northern and southern sand exists and lies south of the lithologic boundary between the Tertiary and Mesozoic rocks because the net direction of littoral drift is southward.

Wind erosion of the beach sand and accumulation of this sand in the dunes normalizes the distribution of the fine sizes. There is an abnormally low amount of fine material in the beach sand reflected by breaks in slope of cumulative curves at the fine sizes. Cumulative curves of dune sand show no breaks in slope in the finer sizes.

Coplotting of statistical parameters readily separated southern and northern beaches and show that, statistically, southern dunes are transitional between the two. It is not possible to separate northern beaches and dunes by this method. Generally, dune sands are finer, better sorted and more positively skewed than beach sands. Mesokurtism seems to be characteristic of dune sand but platykurtism and leptokurtism are possible.

Specific beach-dune pairs, that is beaches and adjacent dunes, show that erosion of beach sand by wind is selective. Sands are eroded from the beach, by wind, in amounts which are directly proportional to availability and inversely proportional to phi size.

The lower limit of size in dune sand is determined by the sorting effect of waves in the parent beach environment.

MINERALOGY

Introduction

Mineralogically the southern beach sands are complex, while northern beach sands exhibit a simpler mineralogy (Fig. 10). Northern sands are impure arkoses and southern sands are feldspathic graywackes (Fig. 11) (Folk, 1961, p. 111). Complex sedimentary, metamorphic and igneous rocks in the Klamath Mountains produce the complex mineralogy of the southern beaches. Tertiary sedimentary and igneous rocks and Quaternary terrace deposits produce the less complex mineralogy of the northern beaches. If in the future the sediments along the Oregon coast become lithified the resulting sandstone unit will be an arkose on the north and a graywacke on the south. No major differences exist in weathering, erosion or deposition of the sediments; the only major difference lies in their source areas.

Most present workers believe that the Klamath Mountains were a major source area for the Tertiary sediments to the north. Assuming that sediments presently being derived from the Klamath Mountains are not decidedly different from those derived during Tertiary time, the mineralogy of Tertiary sandstones should be similar to the mineralogy of southern beach sands. Significant differences in quartz and feldspar petrology are found when the mineralogy of the two areas is compared, suggesting that the Klamath Mountains were not a major source of the Tertiary sediments.

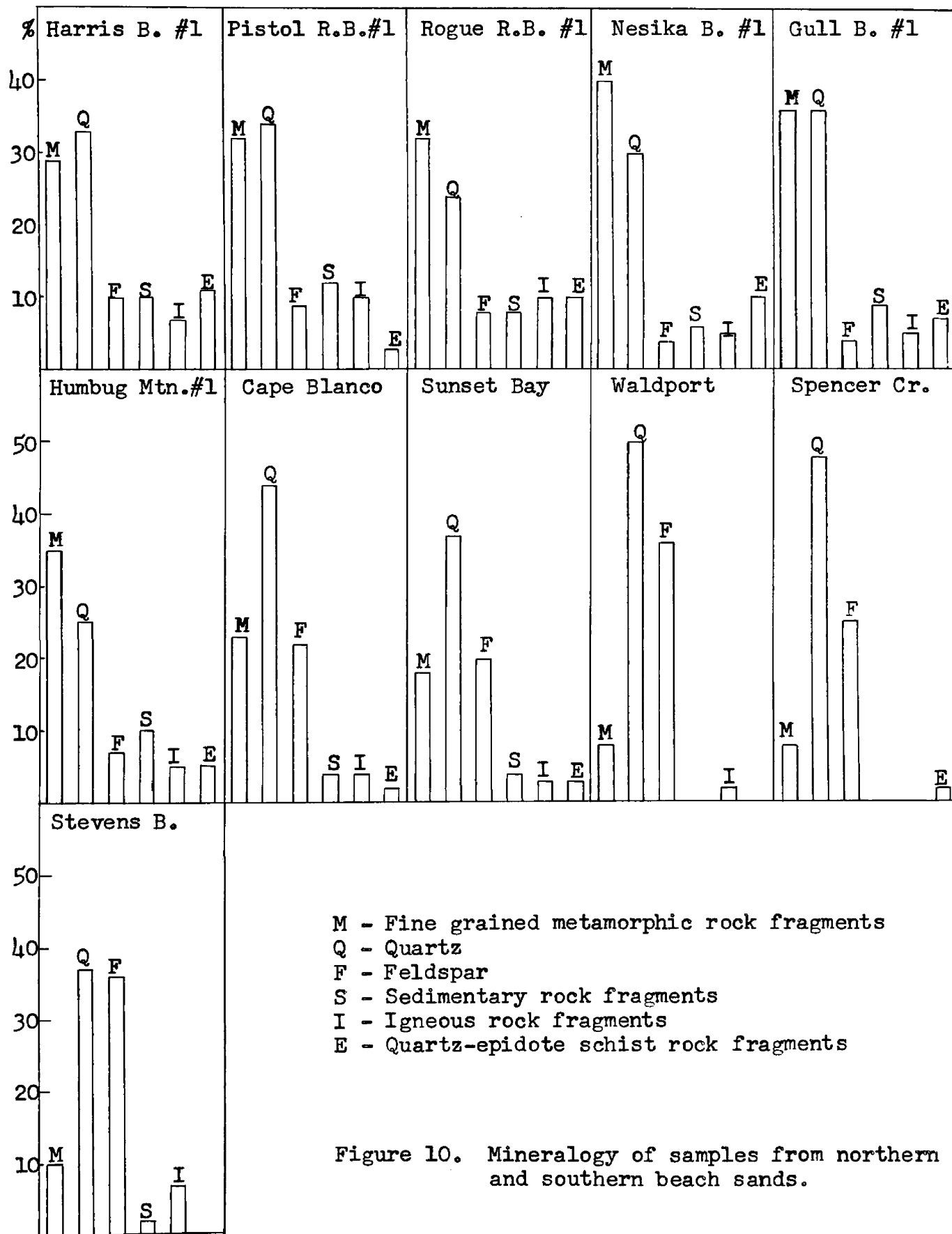


Figure 10. Mineralogy of samples from northern and southern beach sands.

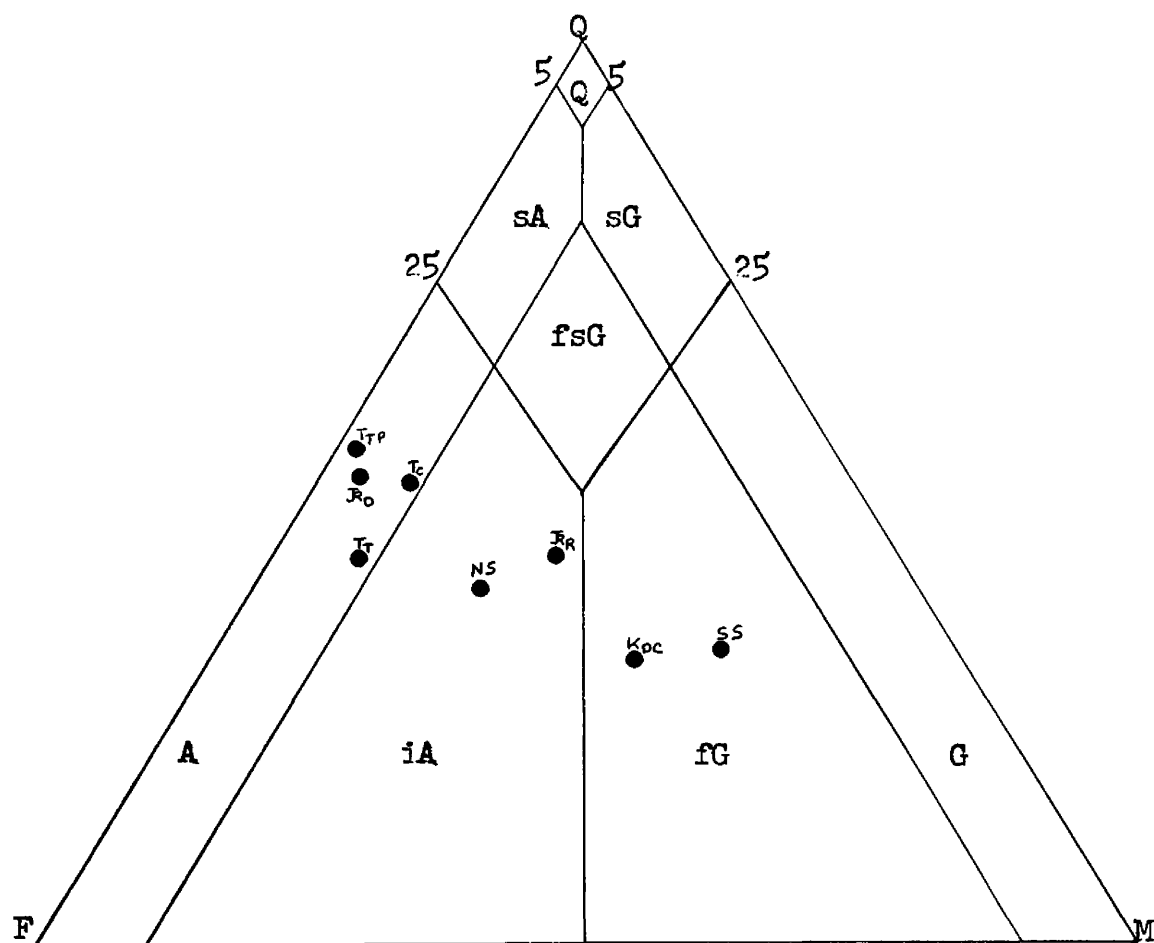


Figure 11. Rock nomenclature triangle (after Folk, 1961, p. 111)

Poles

- Q - quartz plus chert
- F - feldspar plus igneous rock fragments
- M - metamorphic rock fragments

Areas

- A - quartzite
- sA - subarkose
- sG - subgraywacke
- A - arkose
- iA - impure arkose
- fG - feldspar graywacke
- G - graywacke

Plots

- NS - northern sands
- SS - southern sands
- TTP - Tunnel Point
- TC - Coaledo
- KDC - Days Creek
- JR_R - Riddle
- JR_D - Dothan

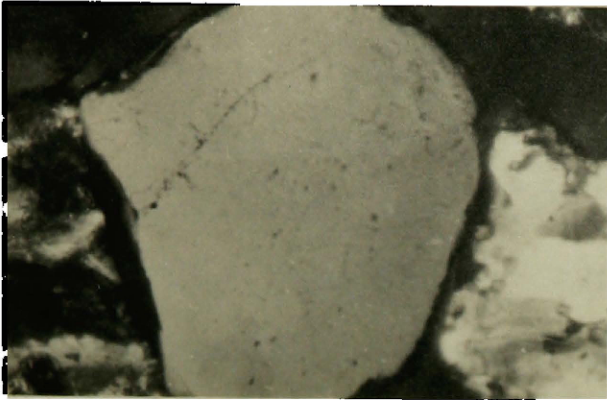


Figure 1. Plutonic Quartz

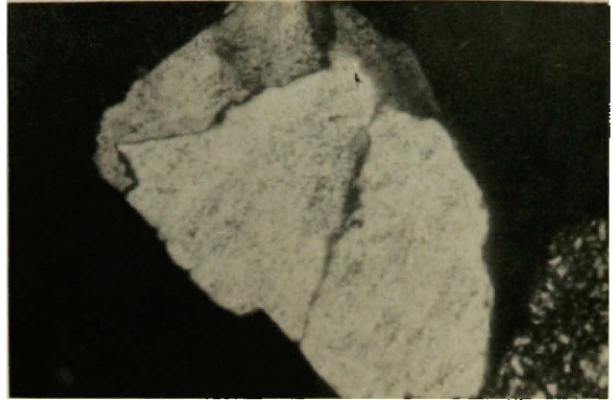


Figure 2. Vein Quartz

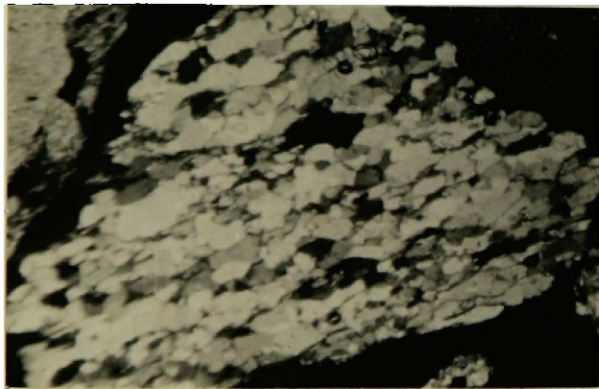


Figure 3. Recrystallized Metamorphic Quartz



Figure 4. Schistose Metamorphic Quartz



Figure 5. Stretched Metamorphic Quartz

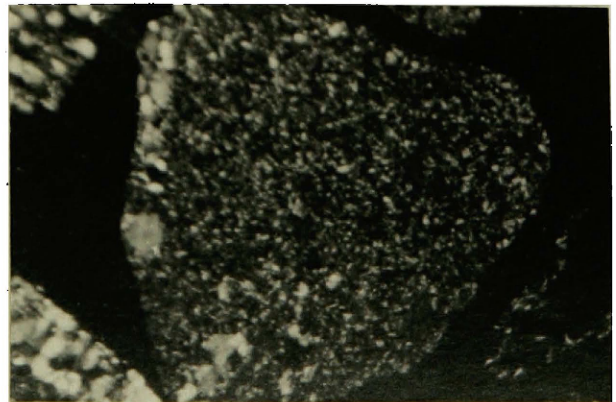


Figure 6. Fine-grained Metamorphic Rock Fragments

Plate 1. Photomicrographs of major quartz types and fine-grained rock fragments.

Quartz Petrology

Krynine (1940) has proposed a classification of quartz grains found in sediments from which one may deduce the nature of the source area. Folk (1961, pp. 68-71) modified this somewhat and his version is used here. Differentiation of quartz types is based on grain shape, strain shadows, inclusions, vacuoles and simple versus composite grains. Theoretically certain quartz grains are characteristic of particular sources. Volcanic quartz is clear and characterized by its bipyramidal shape. Plutonic quartz (Plate 1, Fig. 1) derived from batholiths and stocks occurs as simple grains containing a few inclusions and vacuoles and showing slight if any strain shadows. Vein quartz (Plate 1, Fig. 2) consists of composite grains which have close optical orientation, many vacuoles and inclusions. Quartz from metamorphic rocks is divided into three categories, recrystallized metamorphic quartz, schistose quartz and stretched metamorphic quartz. Recrystallized metamorphic quartz (Plate 1, Fig. 3) grains are composite and show little strain, because recrystallization destroys previous strain shadow and, unless stress is subsequent to recrystallization, no strain shadows will be present. Differing optical orientation of the original sedimentary grains gives the recrystallized metamorphic composite grain a mosaic appearance. Individual grain boundaries are not sutured or crenulated. Schistose quartz (Plate 1, Fig. 4) is characterized by rather elongate or platy grains resulting from lit-par-lit injection of quartz between cleavage planes of micaceous schist. Grains are composite and show little strain. Stretched metamorphic

(Plate 1, Fig. 5) quartz results from shearing of quartzose rocks without recrystallization of the quartz. The resulting quartz is commonly composite with sutured individual grain boundaries and displays marked strain shadows. Composite grains that fracture and disintegrate along the boundaries of the original grains produce simple grains that are difficult or impossible to tell from other types of quartz.

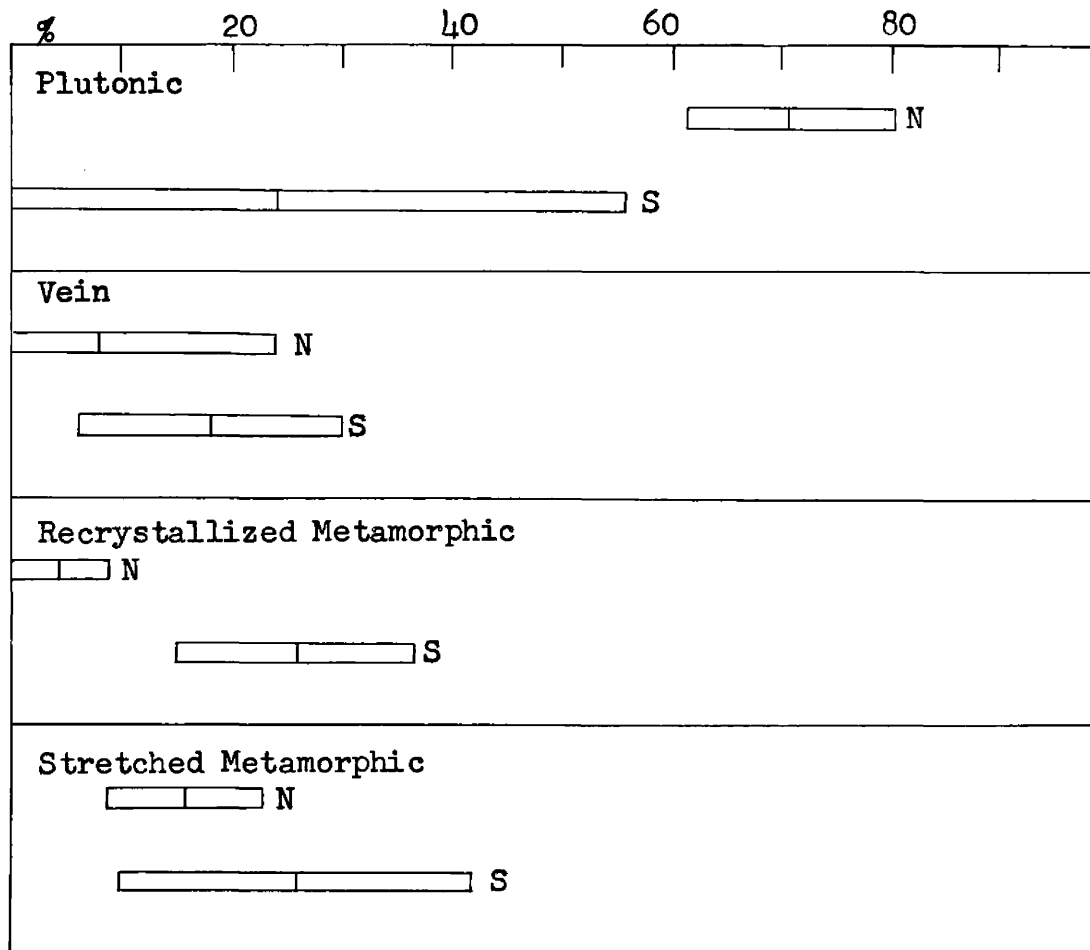


Figure 12. Percent of major quartz types in northern and southern beach sand. Three standard deviations of percent plotted on either side of the arithmetic mean.

Southern beaches are composed of abundant amounts of composite quartz grains and thus can be classified with reasonable assurance. Figure 12 illustrates the percents of each quartz type found in

southern beach sands. More than 50% of the quartz was derived from metamorphic rocks or from quartzose rocks which have been strained or recrystallized. The quartz alone shows that the source area was in part metamorphic. Plutonic quartz suggests a source of silicic intrusive rocks perhaps in association with quartz veins.

Theoretically, the following geologic history of the Klamath Mountains can be deduced by analysis of quartz types alone. The recrystallized metamorphic quartz indicates that at some time quartzose sands and silts were deposited. This may also be inferred from the stretched composite metamorphic quartz. Plutonic rocks were emplaced as evidenced by vein and plutonic quartz. At the same time the sediments were folded and metamorphosed thus producing the metamorphic quartz types from the older sediments. This historical deduction based on quartz types compares favorably with Baldwin's (1959) historical interpretation of the Klamath Mountains. Of course the history is sketchy but it points out that the analysis of quartz types is a useful tool in determining the nature of source areas.

Quartz types from northern sand, southern sand and Tertiary sedimentary rocks may indicate the origin of northern sand and Tertiary sandstones. Most present workers consider that the Klamath Mountains were a major source for the Tertiary sedimentary rocks to the north. Assuming that quartz presently being derived from the Klamath Mountains is similar to that derived during Tertiary time, then quartz types from southern sand should be similar to quartz types found in Tertiary sedimentary rocks. Chi square tests were run comparing percents of each quartz type from samples of southern sand and Tertiary sandstones.

The probability that quartz types from the two sets of samples are proportionately the same is less than .001. If the Klamath Mountains were a common source then a much more favorable comparison would be expected. On the basis of quartz types then, the Klamath Mountains were not a major source for the Tertiary sedimentary rocks.

Several T tests (Folk, 1961, p. 57) comparing total quartz content of samples from southern beach sand, northern beach sand and Tertiary and Mesozoic sandstones show that the southern beach sand has an abnormally low quartz content when compared to the other areas. Dilution of southern beach sand by rock fragments causes the low quartz percent. Quartz types in northern beach sand compare favorably with those found in Tertiary sandstones but do not correlate with southern beach sand quartz types. Thus, the northern beach sand is derived from Tertiary sandstones along the north coast.

Feldspar Petrology

Southern beach sands contain less than 10% feldspar (Fig. 10). Roundness determinations (Powers, 1953) show that the feldspar is subangular to subround. Weathering is slight and most grains appear fresh. Both orthoclase and plagioclase are present but orthoclase is more abundant by a ratio of about 3 to 2. Northern beach sands contain approximately 30% subangular to subround, fresh feldspar. Orthoclase is nearly twice as abundant as plagioclase.

The availability of feldspar in low grade metamorphic and sedimentary rock terrains is thought to be very limited (Folk, 1961, p. 80; Pettijohn, 1957, p. 513). Low grade metamorphic and sedimentary rocks

constitute the Klamath Mountains and sedimentary rocks make up most of the Coast Range Mountains. However the Klamath Mountains do have granitic stocks and ultrabasic intrusives and the Coast Range Mountains have basaltic volcanic rocks. These rock types could contribute feldspar to sediments along the coast. In the Klamath Mountains the granitic stocks and ultrabasic intrusives contribute little feldspar because they are small. The high resistance of the volcanic rocks in northern Oregon appears to minimize the amount of feldspar derived from them. Thus feldspar content of northern and southern beach sands should be low because of the low grade metamorphic and sedimentary source rocks.

Neither Folk nor Pettijohn state what percentage constitutes a small amount but an upper limit of 10% would seem to be a reasonable figure. The feldspar content of southern beach sand is below 10% and supports the idea that little feldspar originated in regions of low grade metamorphic and sedimentary rocks. However, northern beach sands contain about 30% feldspar. Reasons for the high feldspar content must lie in the mineralogy and physiography of the source area. Samples of three Tertiary sandstones were analysed petrographically and found to contain 20 to 30% of fresh, angular feldspar. On the basis of feldspar content and freshness the northern beach sands have as their chief source the Tertiary sedimentary rocks of the Coast Range Mountains. The reasons for the good preservation of the feldspar will be discussed later in this section. Feldspar found in Mesozoic sedimentary rocks is moderately to highly weathered. Southern beach sands contain quite fresh feldspar. On the basis of freshness it is unlikely that feldspar present in southern beach sands was derived from Mesozoic

sedimentary rocks or their metamorphic counterparts. Volcanic and plutonic igneous rocks of the Klamath Mountains must furnish what little feldspar is found in southern beach sand.

Climatic and physiographic significance of feldspars

The use of feldspar as an indicator of climate and physiography has been proposed (Krynine, 1935). Under warm humid climatic conditions feldspar weathers very rapidly unless relief in the source area is sufficient to promote rapid erosion and burial so that weathering does not run its full course. Coastal Oregon has an average rainfall of 65 to 90 inches a year, most of which falls between October and March. Temperatures vary from about 40° F. in January to about 60° F. in August. Using the Koppen system of climatic classification, the climate is characterized as Csb, in which C represents mesothermal, s represents summer dry and b indicates a median temperature within C (Cooper, 1958, p. 11-13). These conditions should promote rapid weathering of feldspar. However, the Klamath and Coast Range Mountains rise rather steeply at or near the coast. This may result in preservation of feldspar if the effect of relief is greater than the effect of climate. Feldspar from northern beach sand indicates that relief is the greater factor. Both orthoclase and plagioclase feldspars found in northern beach sands are fresh and subangular to subround. In total feldspar percent the northern beach sands are not significantly different from their major source rock, the Tertiary sandstones. Although the feldspar has gone through at least two erosion cycles, its fairly fresh, angular condition has been preserved. Therefore, the

relief of the Coast Range Mountains is great enough to cause sufficiently rapid erosion and burial to offset the weathering effect of the warm humid climate.

Along the southern coast the Klamath Mountains should produce a similar situation. Feldspars found in southern beach sand are also fairly fresh and subangular to subround. It has been pointed out previously that these feldspars could not have come from the Mesozoic sediments but must have originated in the plutonic and volcanic rocks in the Klamath Mountains. Southern beach sand feldspars are primary. If weathering has been effective, then plagioclase should be more highly weathered than orthoclase. Both types of feldspar are weathered to approximately the same degree. Therefore, erosion produced by relatively high relief has been more effective than weathering produced by the warm humid climate.

Possible sources of Tertiary sandstones as indicated by feldspar petrology

Most present workers believe that Mesozoic rocks of the Klamath Mountains were a major source for the Tertiary sediments in the Coast Range Mountains. Southern beach sands are derived chiefly from the Klamath Mountains and therefore should contain feldspar which is similar to that found in the Tertiary sandstones. The total feldspar content of samples of southern beach sand and Tertiary sandstones was compared by means of a T test (Folk, 1961, p. 57). The probability that the total feldspar content of southern beach samples is the same as the total feldspar content of the Tertiary samples is less than .001. That is, in 1000 samples of southern beach sand, less than 1 sample

would contain enough feldspar to compare favorably with the Tertiary samples. A much more favorable comparison would be expected if the Tertiary sandstones and southern beach sands were derived from the same source. Therefore, both quartz and feldspar comparisons dispute the claim that the Tertiary sediments were derived principally from the Klamath Mountains.

Another clue to the possible origin of Tertiary sandstones of the Coast Range Mountains may be furnished by the composition of the feldspar. Some of the plagioclase is fairly fresh and extinction angles on albite twins can be determined. Statistically the procedure is not strictly valid because it is not possible to determine extinction angles for all grains seen in a random count. However, some indication of the mineralogy of the source rocks may be determined. About half of the plagioclase, fresh enough to determine composition, is more calcic than A_{n50} . Plagioclase of this composition is associated with basic and ultrabasic igneous rocks. Because it is easily weathered the source was probably nearby. Basic and ultrabasic igneous rocks are present in the Klamath Mountains, which are very near the Tertiary sandstones. On the basis of this evidence the Klamath Mountains did contribute some, but not a major part of the sediment during Tertiary time. Sodic plagioclase and potash feldspar are also present in the Tertiary sandstones. These indicate a more silicic igneous rock source. Marked zoning of some feldspars indicates that some source rocks were hypabyssal or volcanic in origin. From these lines of reasoning several additional areas containing a wide variety of rock types must have been sources for the Tertiary sedimentary rocks.

Fine Grained Rock Fragments

Some of the most abundant constituents of southern beach sand are dark, fine grained, siliceous rock fragments of doubtful origin. It is this type of rock fragment that gives southern beaches their dark color. Several varieties are present and there appear to be transitions among them all. The most abundant variety is very fine grained and gray with little distinction between grains and matrix. In most cases no distinct grains are visible and the fragments appear as a subdued gray mosaic of what appears to be quartz (Plate 1, Fig. 6). X-ray patterns from this variety show the presence of quartz or chert, chlorite, feldspar and small amounts of biotite. This composition suggests that the rock is a metamorphosed fine grained siliceous sediment. Where grains and matrix are discernible, very minute grains of quartz occur in a matrix of clay which generally shows a high degree of alteration to chlorite. Where differentiation of grains and matrix can not be made the rock fragments appear cherty. Some of the dark material is chert but most of it is a fine grained siliceous sediment which has undergone some metamorphism. Two other varieties show grains and matrix which are readily discernible. The difference among these lies in the matrix material. One contains minute quartz grains in a black matrix. This is probably a more carbonaceous facies of the fine grained sediment. The other variety contains similar grains but has a red matrix because of the presence of iron. Both varieties show schistosity.

The fine grained gray rock fragments occur in sediments younger than late Jurassic. At Sisters Rocks the seaward pinnacle is in part composed of fine grained, siliceous material mapped as the early-late Jurassic Galice Formation (Geologic Map of Western Oregon, 1961). Here the early Cretaceous Days Creek Formation lies unconformably on the Galice. Fragments of this rock type are found in the early Cretaceous Days Creek Formation and the very late Jurassic Riddle Formation. None were seen in the analysis of Tertiary sedimentary rocks. Therefore, the fragments were eroded from prelate Jurassic metamorphosed rocks and deposited in the Cretaceous sediments. Thus the rock fragments found in beach sand come from not only the metamorphosed prelate Jurassic rocks, but from Cretaceous rocks of the Klamath Mountains as well.

The dark, fine grained rock fragments found in beach sand are metamorphosed sediments and chert. There is gradation between the varieties indicating that they represent various facies of the same rock type. Chert may be interbedded with these facies. A more critical study of the Mesozoic rocks is needed to determine positively the above relationships.

Sedimentary Rock Fragments

Between 5 and 10% of the southern beach sand is composed of sedimentary rock fragments. The northern beach sands have about 2% sedimentary rock fragments. Matrix and grains within each fragment are clearly visible, and in most fragments the matrix shows some alteration to chlorite. Grains are fine, angular to subangular quartz,

feldspar and fine grained metamorphic rock fragments of chert.

Fragments of fine grained metamorphic rock or chert are found in all thin sections of rocks except those of the late Jurassic Dothan Formation. Grains of this rock type are present in the sedimentary rock fragments found in the beach sand. Therefore, the sedimentary rock fragments must be post-late Jurassic. Tertiary sedimentary rocks are not resistant enough to have produced the sedimentary rock fragments. Thus, resistant very late Jurassic and Cretaceous sedimentary rocks must produce the sedimentary rock fragments.

From the presence of these rock fragments in northern beach sand it is evident that either they have weathered from the Tertiary sedimentary rocks or have been transported northward from the southern beach sand. These rock fragments could not withstand two erosion cycles and therefore probably did not originate in the Tertiary rocks. The sedimentary rock fragments must have been transported north from the region of southern beach sand.

Quartz-Epidote-Chlorite Schist

Rock Fragments

A small amount of quartz-chlorite-epidote schist rock fragments occur in southern beach sand. These rock fragments come from the metamorphosed rocks of the Klamath Mountains. Very small amounts of these rock fragments are present in northern beach sands, indicating that some northward littoral drift does occur.

Igneous Rock Fragments

For the most part igneous rock types occur as basaltic volcanic rock fragments with minute lath-like plagioclase in a brown ground-mass. These comprise less than 10% of southern beach sand and only a few percent of northern beach sand. In both cases the fragments originate in volcanic rocks found in the two source areas.

Transition Zone

As previously pointed out beach sand from Cape Blanco, within the region of southern sand, is texturally transitional between northern and southern sand (Fig. 10). The overall mineralogy of Cape Blanco sand is also transitional (Fig. 10). The net direction of littoral drift is southward because Cape Blanco is south of the Tertiary-Mesozoic lithologic contact and because the mineralogy is more like northern than southern sand.

Mineralogy as an Indication of Littoral Drift

Theoretically along a coast where prominent headlands and short narrow beaches occur, and where lithologies change along the coast, there should be differences in mineralogy from one beach to the other. If littoral drift is pronounced enough to mix the sands, this will produce a uniform mineralogy along much of the coast. If mineralogy is determined with respect to phi sizes, then the size at which littoral drift begins can be determined. The southern Oregon coast has rather short, narrow beaches, prominent headlands and lithologic changes

parallel to the coast. Mineralogy of each phi size was determined for six beaches along Oregon's south coast and chi square tests were run to compare the mineralogy of adjacent beaches. A probability of .025 was chosen as the limit of correlation. Favorable comparisons are found in the majority of cases at sizes smaller than .5 ϕ (Fig. 13).

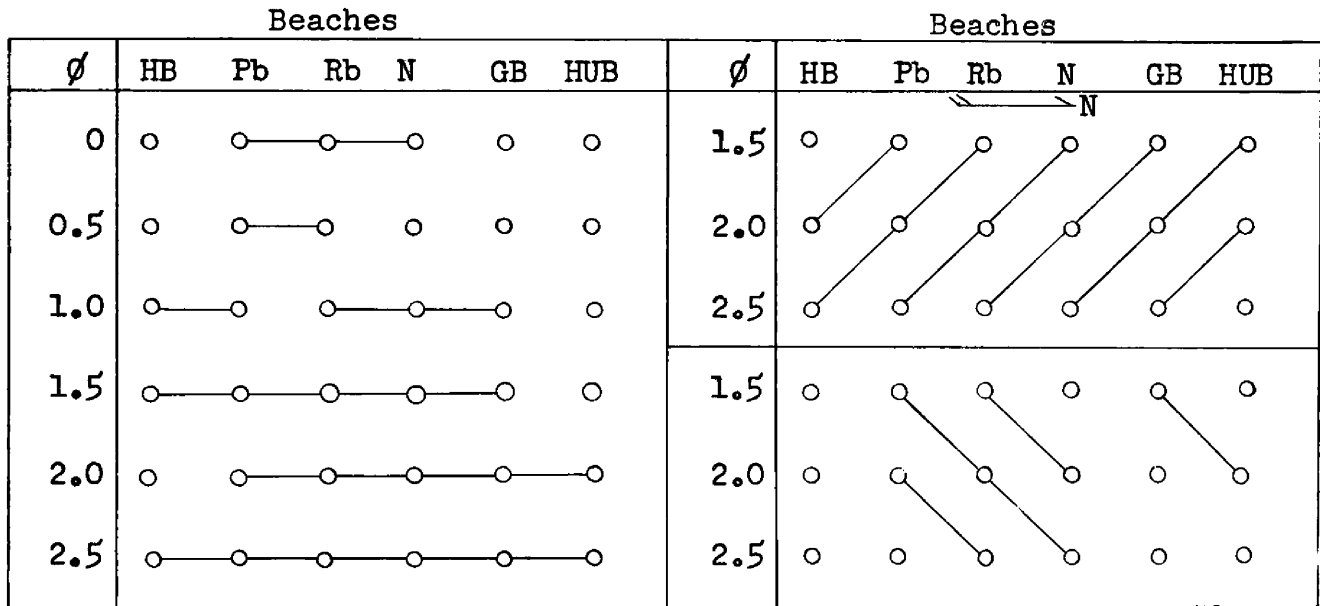


Figure 13. Chi square tests of phi size mineralogy. Solid lines indicate favorable comparisons.

Only three beaches have favorable correlations above 1 ϕ and these are located near river mouths where sediments carried in by the rivers cause favorable comparisons. Sediments at Humbug Mountain show correlation with Gull Beach sands only in sizes smaller than 1.5 ϕ . Therefore sizes larger than 2 ϕ do not migrate around Humbug Mountain, which extends half a mile out to sea.

Because favorable correlations were found in the majority of cases below .5 ϕ littoral drift begins at 1 ϕ except where very large headlands prevent it. At sizes of about 1.5 ϕ and smaller littoral

drift is very pronounced and below 2 ϕ mixing of sand is complete.

Having established the size below which littoral drift is pronounced, it may be possible to determine the net direction of movement by a similar method. Sedimentary particles are worn down during transportation. Therefore, if it can be shown statistically that correlations between a phi size from one beach and the next lower phi size from an adjacent beach are favorable, then a net direction of movement may be inferred. Sizes of 1.5 ϕ and smaller have been shown to be relatively mobile under the effect of longshore currents. Using 1.5, 2 and 2.5 ϕ sizes for comparison, chi square tests were run on six southern beaches (Fig. 13). A phi size from one beach was compared with the next lower size from the next northern and southern beach. All of the tests comparing larger sizes of one beach with smaller sizes of the next southern beach gave good correlation. Only half of the comparisons involving larger southern and smaller northern sizes compared favorably. Net southward littoral drift is indicated on the basis of these tests.

Petrography of Tertiary and Mesozoic

Sedimentary Rocks

Introduction

Beach sands are derived chiefly from rocks of the Coast Range and Klamath Mountains and therefore a petrographic study of some of these rocks gives an indication of the minerals available for accumulation on the beaches. Because comparisons are made with beach sand it seems reasonable to study those parts of the formations which are

texturally similar to beach sand. The following descriptions do not apply to the entire formations but only to the medium to coarse grained facies which crop out along the immediate coast. However, it is assumed that these samples are representative of such facies throughout the formation.

Dothan Formation (Late Jurassic)

Medium to coarse grained facies of the Dothan Formation are arkosic (Folk, 1961, p. 111) (Fig. 11). Plutonic quartz is the most abundant quartz type making up about 30% of the total. Vein quartz comprises about 15%, stretched metamorphic quartz 10%, and recrystallized metamorphic quartz 5%. 30% of the grains are orthoclase and plagioclase feldspar, most of which show a moderate degree of weathering. Volcanic rock fragments constitute the remaining 10%.

Riddle Formation (Late Jurassic)

The Riddle Formation is a coarse grained, angular to subangular impure arkose (Folk, 1961, p. 111) (Fig. 11). 25% of the grains are plutonic quartz; 15% are stretched metamorphic quartz; vein and recrystallized metamorphic quartz each make up 5% of the total grains. Feldspar is highly weathered and comprises about 10%. Volcanic and metamorphic rock fragments constitute about 15% each.

Days Creek Formation (Early Cretaceous)

Medium to coarse grained facies of the Days Creek Formation are feldspathic graywackes (Folk, 1961, p. 111) (Fig. 11). Grains are angular to subangular. Recrystallized metamorphic quartz is the most

abundant quartz type, comprising 15% of all the grains. Plutonic and stretched metamorphic quartz each account for 10% of the total grains. A few grains of vein quartz are present. Moderately to highly weathered orthoclase and plagioclase feldspar composes about 20%. Volcanic rock fragments make up 10%; most are basaltic. The remaining grains are predominantly metamorphic rock fragments. Fine grained metamorphic rock fragments similar to those in southern beach sand are most abundant.

Tyee Formation (Middle Eocene)

The Tyee Formation is a medium to coarse grained arkose (Folk, 1961, p. 111) (Fig. 11). Approximately 35% of the grains are plutonic quartz. A few percent are recrystallized metamorphic quartz. Orthoclase and plagioclase feldspar, in about equal amounts, make up 30% of the grains. Feldspars range from fresh to deeply weathered. Volcanic and metamorphic rock fragments constitute about 15% of the grains.

Coaledo Formation (Late Eocene)

The Coaledo Formation is a coarse grained, angular, bimodal arkose (Folk, 1961, p. 111) (Fig. 11). Plutonic quartz makes up about half of the grains. A few percent of vein, recrystallized metamorphic and stretched metamorphic quartz are also present. Orthoclase and plagioclase constitute about 25%. Some of the feldspar is distinctly zoned. Fresh and highly altered feldspar occur in approximately equal amounts. Volcanic rock fragments make up 20% of the grains. A few fine grained metamorphic rock fragments were seen.

Tunnel Point Formation (Middle Miocene)

The Tunnel Point Formation is a fine grained arkose (Folk, 1961, p. 111) (Fig. 11). Quartz is angular and the greatest percentage is plutonic quartz with a few percent of vein, recrystallized metamorphic and stretched metamorphic quartz. Approximately 30% of the grains are orthoclase and plagioclase feldspar. Orthoclase is the most abundant and comprises about 20% of the grains. Alteration of feldspars is only slight except for a few highly altered plagioclase grains. Rock fragments constitute approximately 10%, most of which are volcanic. Very small percents of biotite, hornblende and zircon were also noted.

Detrital Heavy Minerals

Heavy mineral suites from northern and southern beach sands are composed predominantly of unstable minerals (Table 3). Tourmaline is the only stable major detrital heavy mineral in southern beach sand. Almandite and tourmaline are the major stable heavy minerals in northern beach sand. There is a marked similarity between heavy mineral suites from the two areas. Augite, hornblende, tourmaline, magnetite and epidote are major constituents of both northern and southern beach sand. This points out that littoral drift proceeds north as well as south because such an unstable suite could not have come from the reworked sediments which produce the northern beach sand. Olivine and serpentine, which are very unstable minerals, are present in southern beach sand but absent from northern beach sand. Almandite, a very stable mineral, is present in large amounts in northern beach sand but

present in only small amounts in southern beach sand.

Angular euhedral and well rounded grains of brown tourmaline containing carbonaceous inclusions are present in both northern and southern beach sands. The two distinct shapes indicate two sources. Krynine (1946, p. 69) stated that brown tourmaline containing carbonaceous inclusions is characteristic of sediments derived from low grade metamorphic rocks. The euhedral grains must be derived from low grade metamorphic rocks of the Klamath Mountains. The well rounded tourmaline grains probably come from the Tertiary sedimentary rocks of the Coast Range Mountains which were in part originally low grade metamorphic rocks of the Klamath Mountains.

Heavy Mineral	Northern Sands	Southern Sands
Opagues	VA	VA
Tourmaline	VA	VA
Hornblende	VA	VA
Augite	A	A
Epidote	VA	VA
Almandite	VA	R
Olivine	R	A
Serpentine	R	A
Rutile	R	R
Zircon	R	R
Apatite	R	R

Table 3. Relative amounts of major heavy minerals as determined by rough visual estimate.

VA - very abundant A - abundant R - rare

Conclusions Based on Mineralogic Analysis

Two different source areas along the Oregon coast produce beach sands which are texturally and mineralogically different. The northern

sands are arkoses while the southern sands are graywackes. The approximate boundary is Cape Blanco but there is a transition zone between northern and southern beach sand.

Classification of quartz types (Folk, 1961, pp. 68-71) is a useful tool in determining the nature of source areas of the texturally submature to mature sands. Difficulties arise if the quartz is fine grained because part of the identification depends on the composite composition of grains. Southern beach sand is coarse and the study of quartz types gives a good indication of the lithology and geologic history of their source area, the Klamath Mountains.

Mesozoic rocks of the Klamath Mountains give rise to southern beach sand. On the basis of quartz types, Tertiary sedimentary rocks were not derived chiefly from Mesozoic rocks of the Klamath Mountains. Weathering and erosion of Tertiary sedimentary rocks and Quaternary deposits produces most of the beach sand along the north coast as indicated by comparison of quartz types.

Relief in the Klamath and Coast Range Mountains is sufficient to cause rapid enough erosion and deposition to prevent weathering of feldspar even though western Oregon is warm and humid. Feldspar in southern sand is first cycle while that of northern sand is second or third cycle. The fresh, angular condition of feldspar in medium to coarse grained Tertiary sedimentary rocks indicates that most of it could not have been derived from Mesozoic sedimentary or metasedimentary rocks of the Klamath Mountains. The reason for this is that the feldspar in the Mesozoic rocks is moderately to highly weathered. However, the composition of some plagioclase in Tertiary sedimentary

rocks suggests that a least part of the Tertiary sedimentary rocks came from the Klamath Mountains.

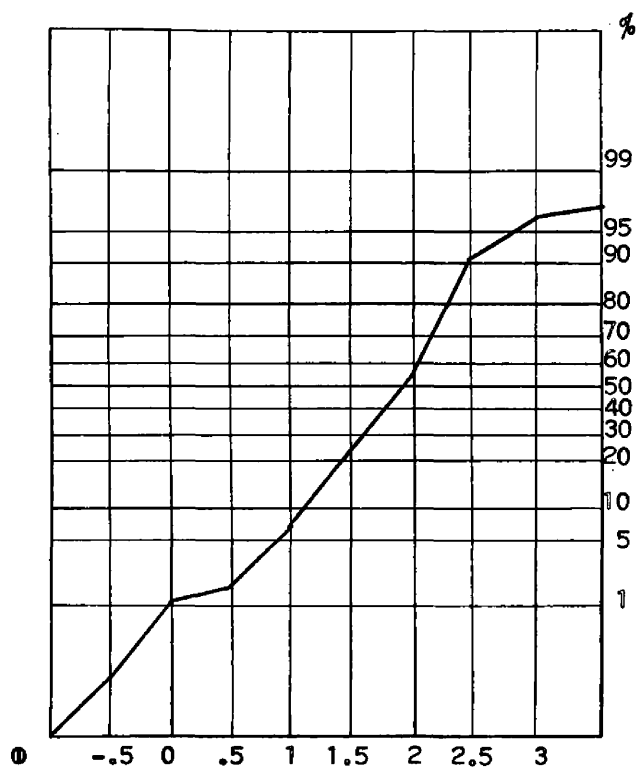
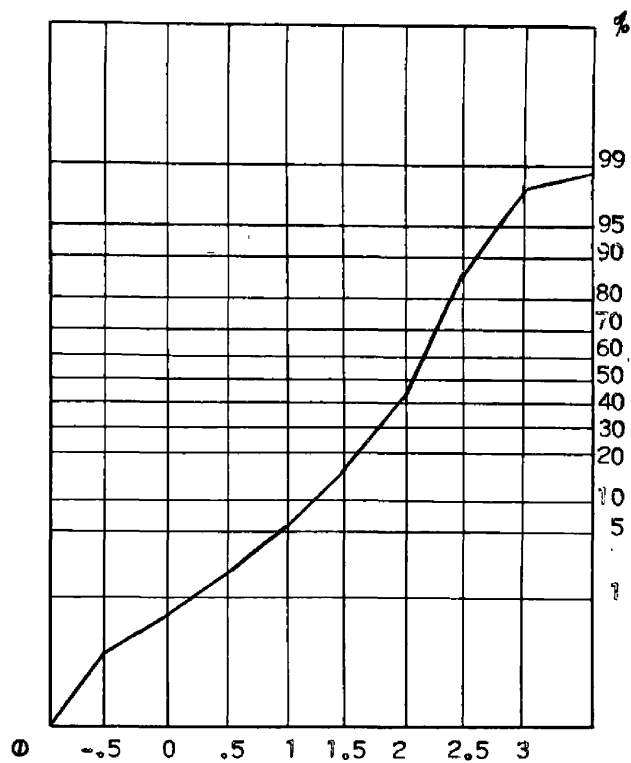
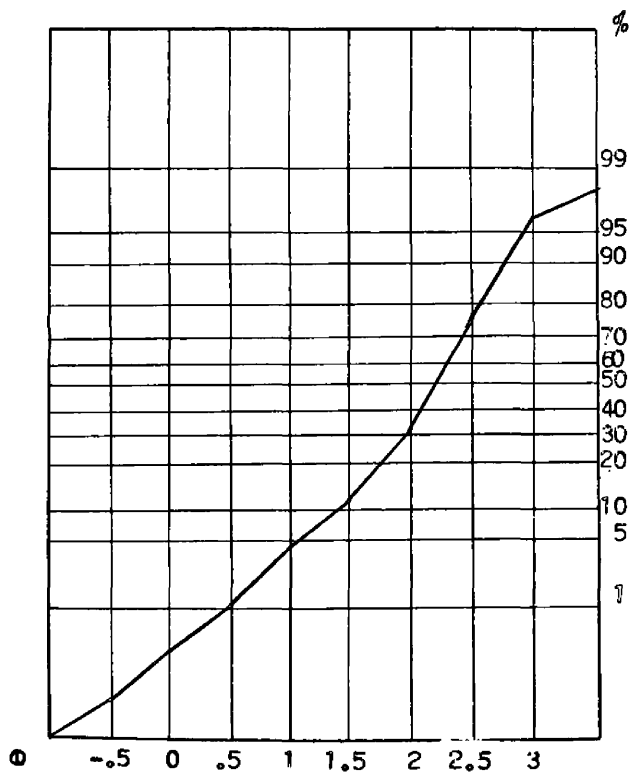
Mineralogy of sand from Cape Blanco supports the previous conclusion that there is a transition zone between northern and southern sand. This transition zone extends south of the lithologic contact between Tertiary and Mesozoic rocks because of the net southward littoral drift. Comparison of phi size mineralogy adds weight to the argument that the net direction of littoral drift is southward. Littoral drift along the coast is most pronounced in sizes smaller than 10 ϕ .

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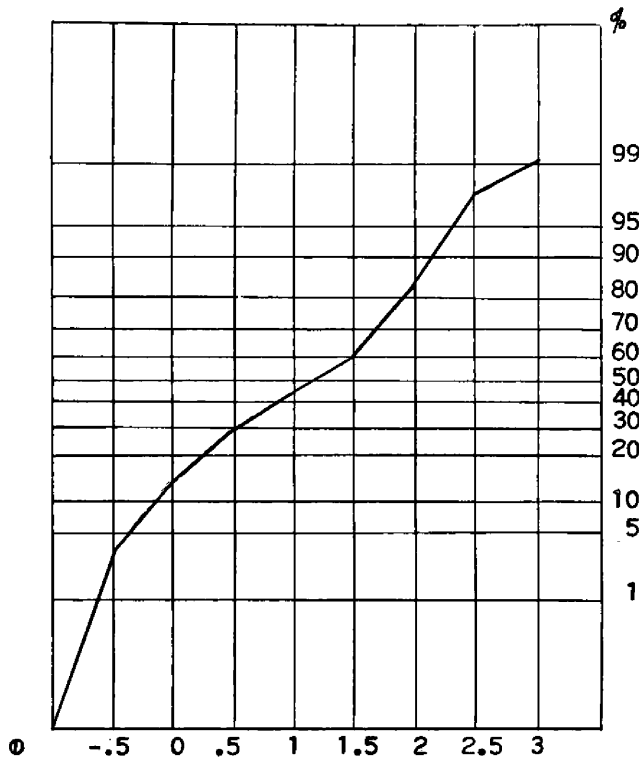
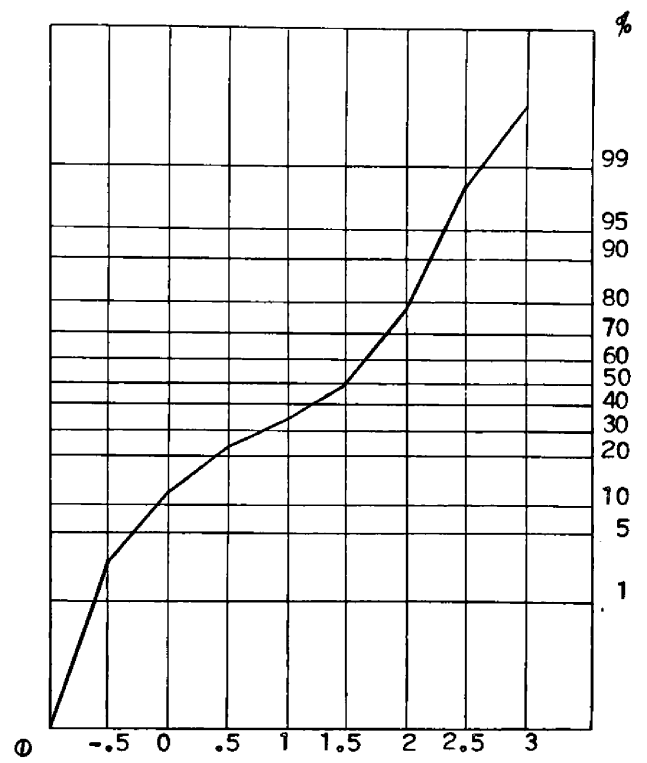
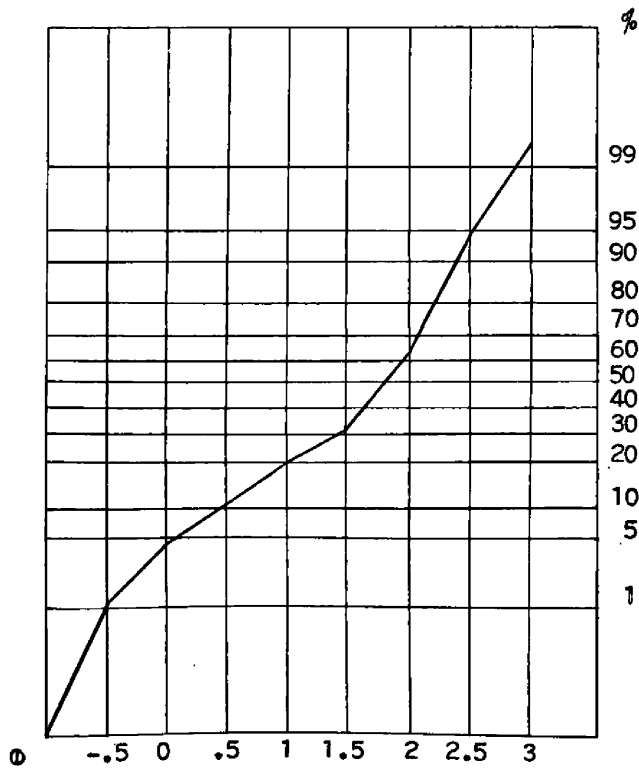
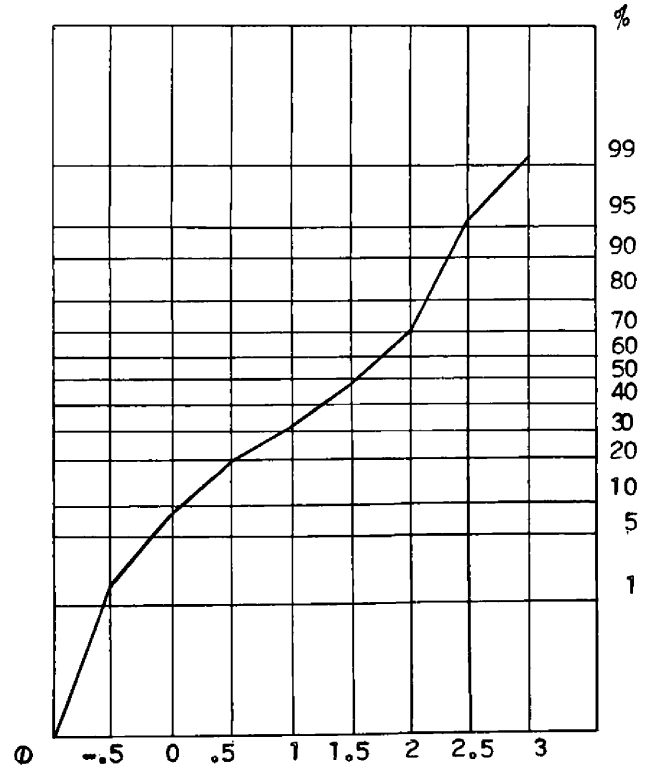
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APPENDIX

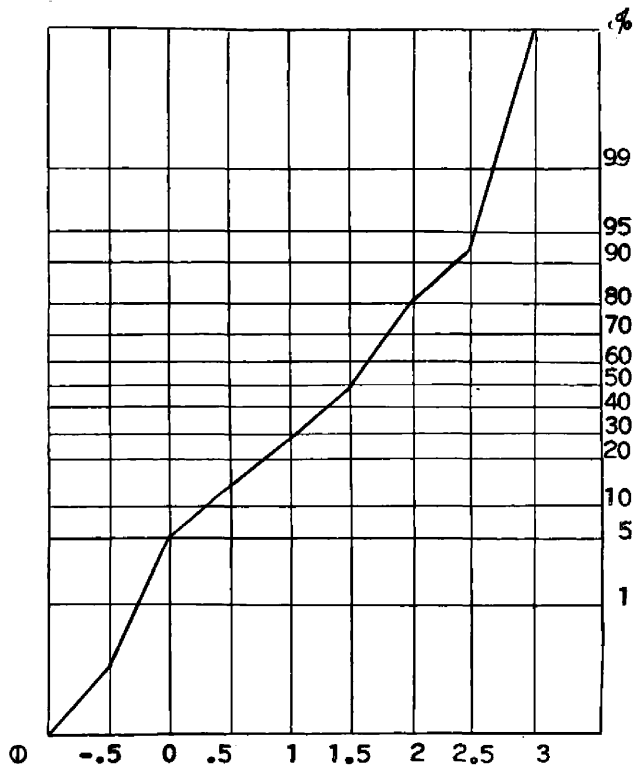
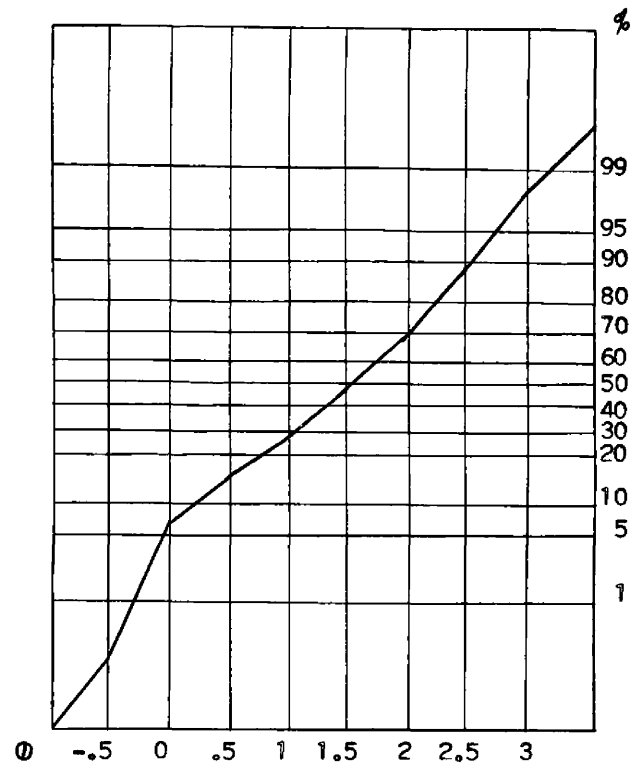
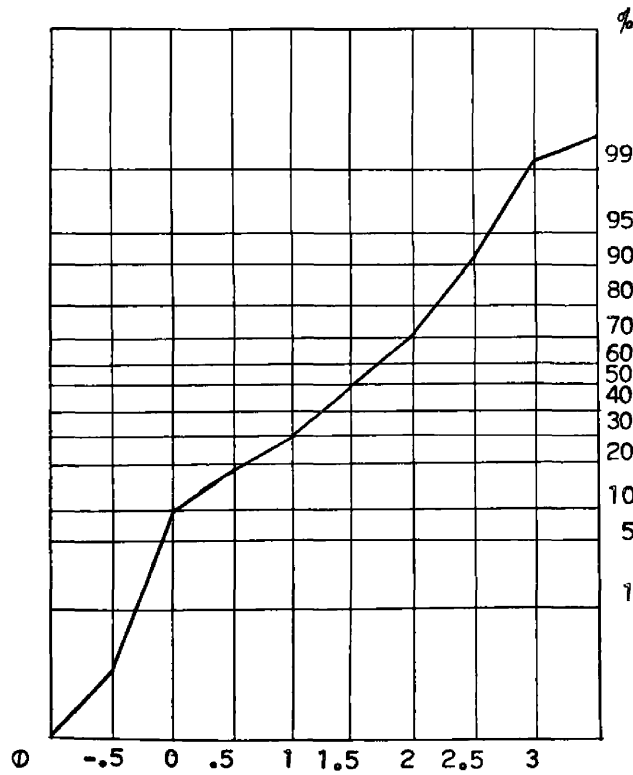
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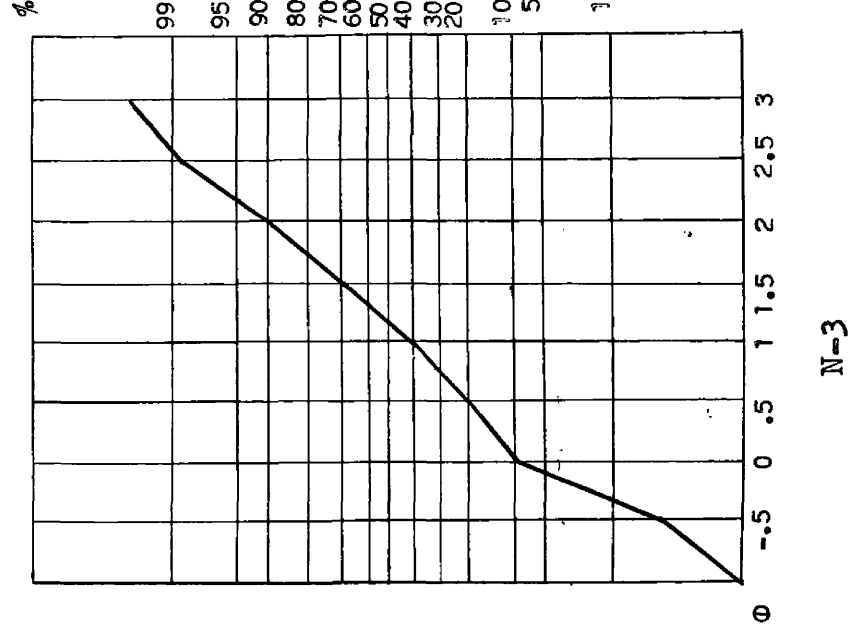
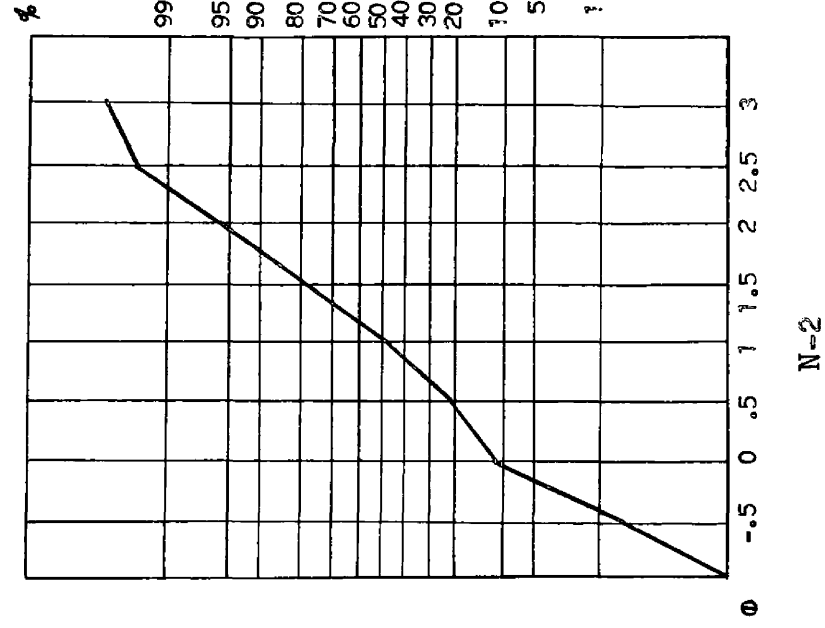
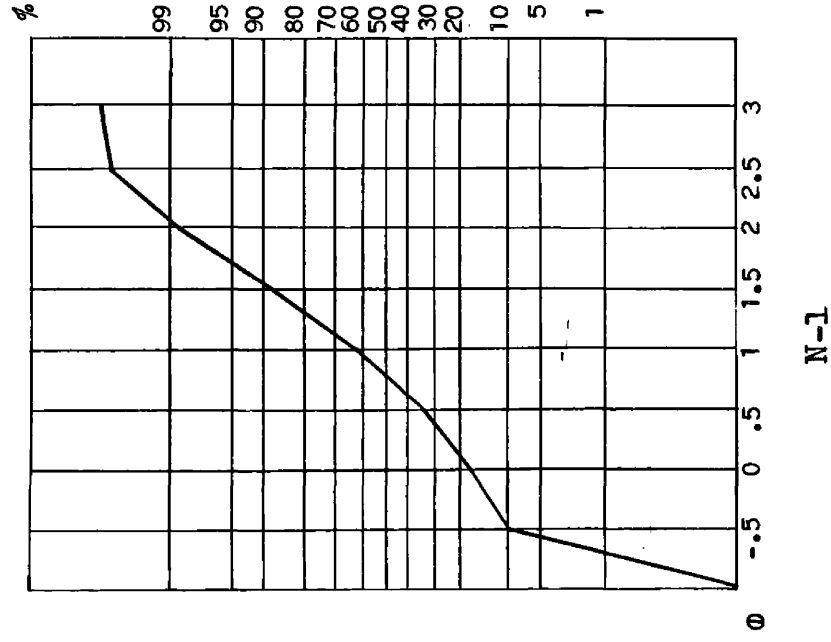
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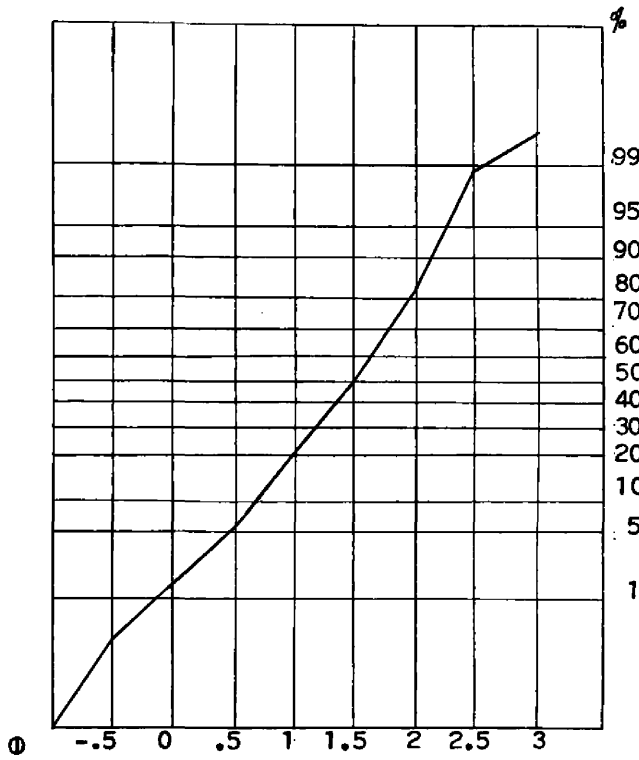
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 $R_B - 1$  $R_B - 2$  $R_B - 3$

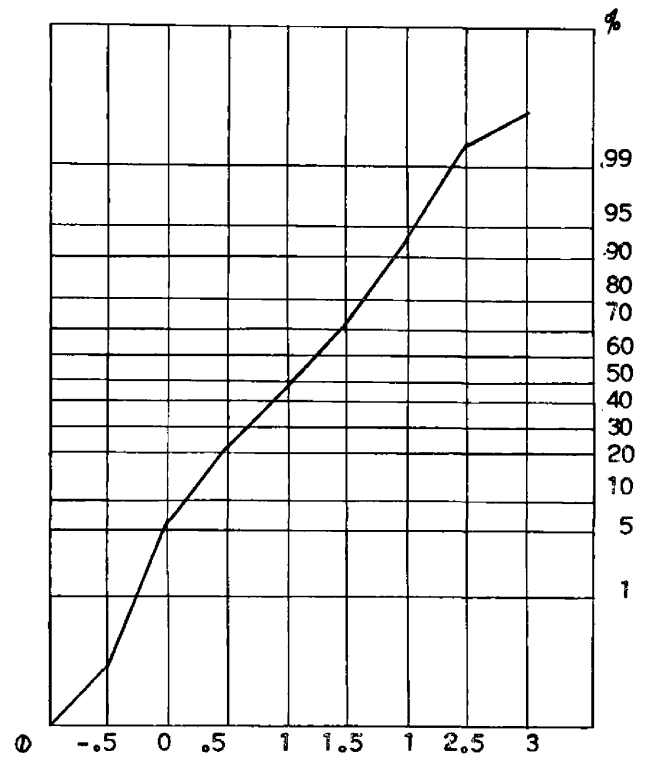
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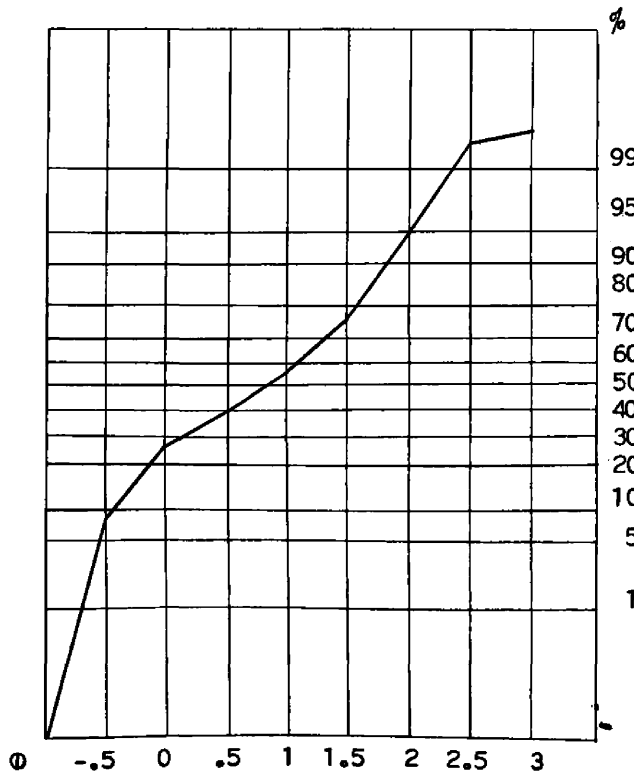
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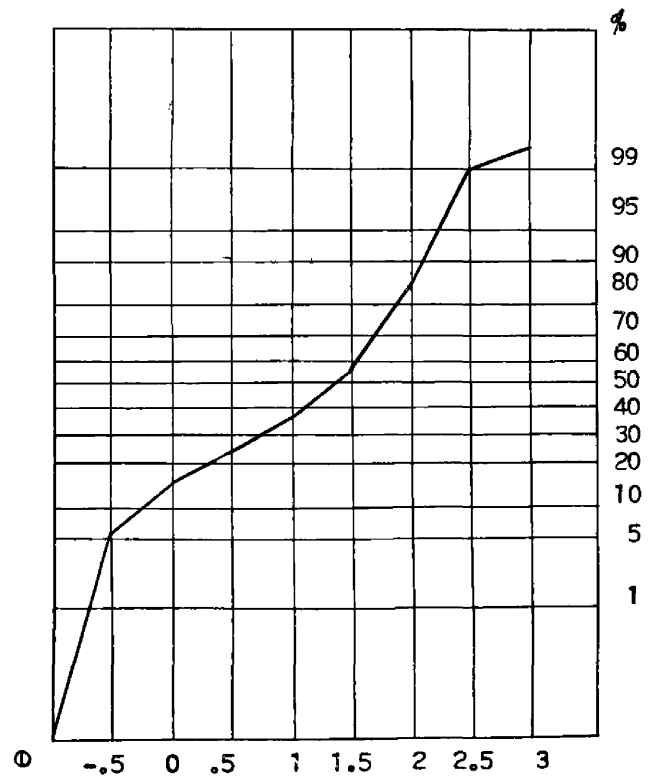
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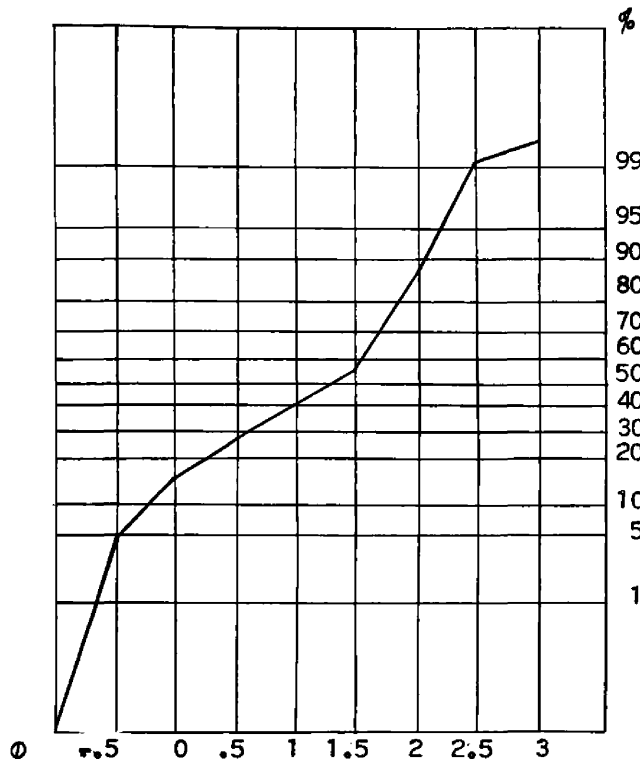


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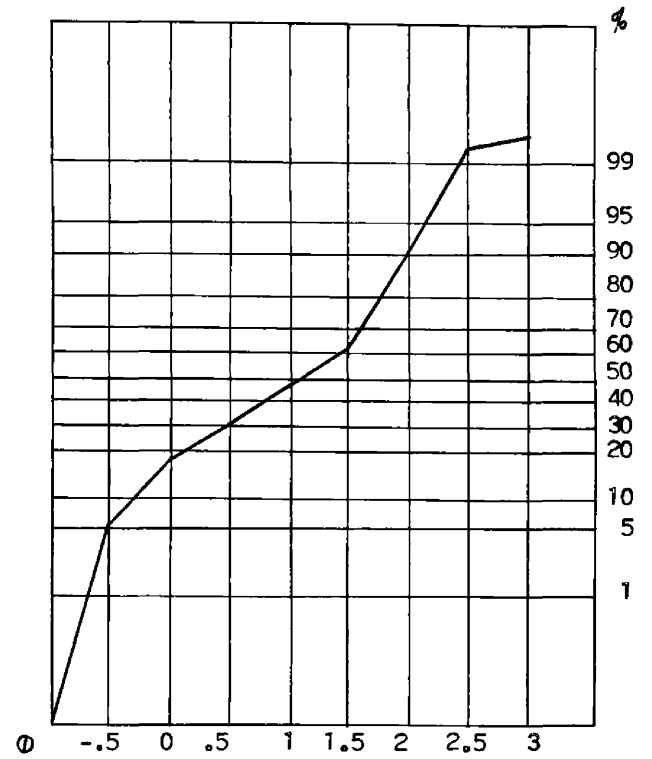


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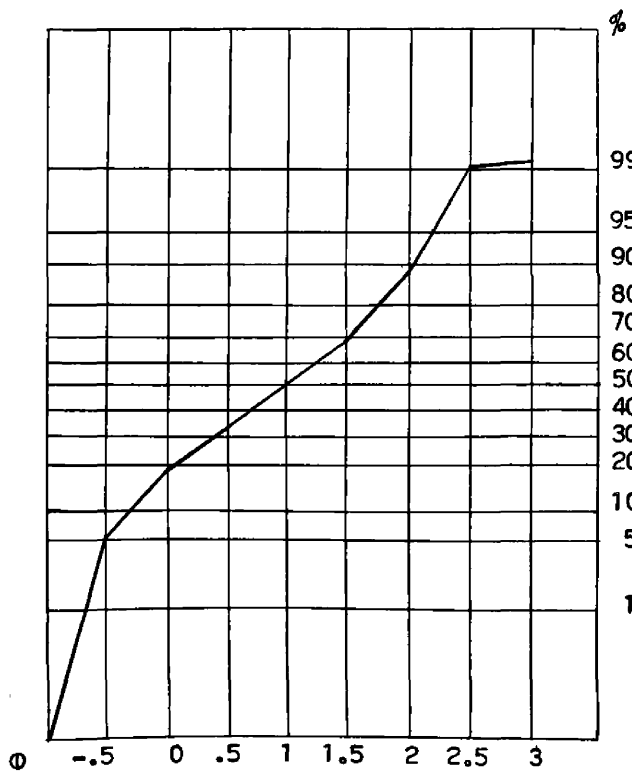
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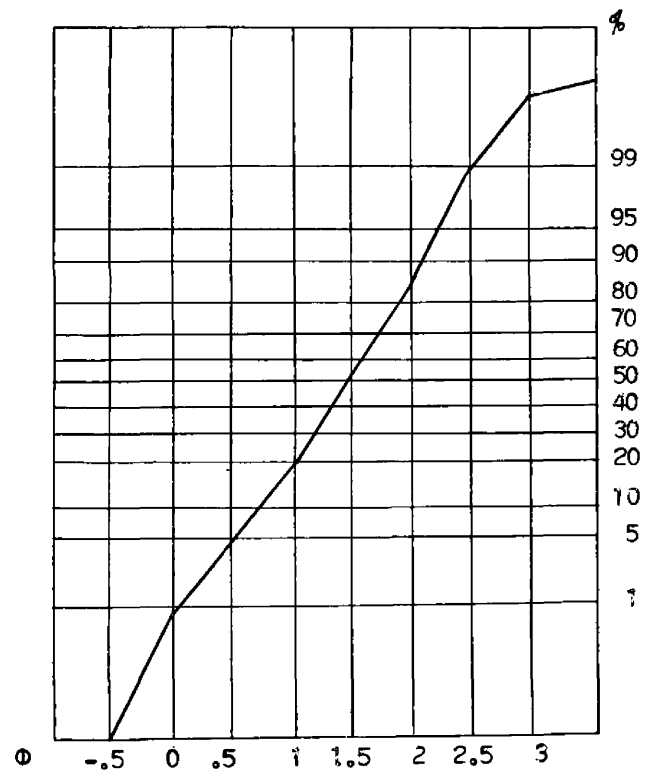
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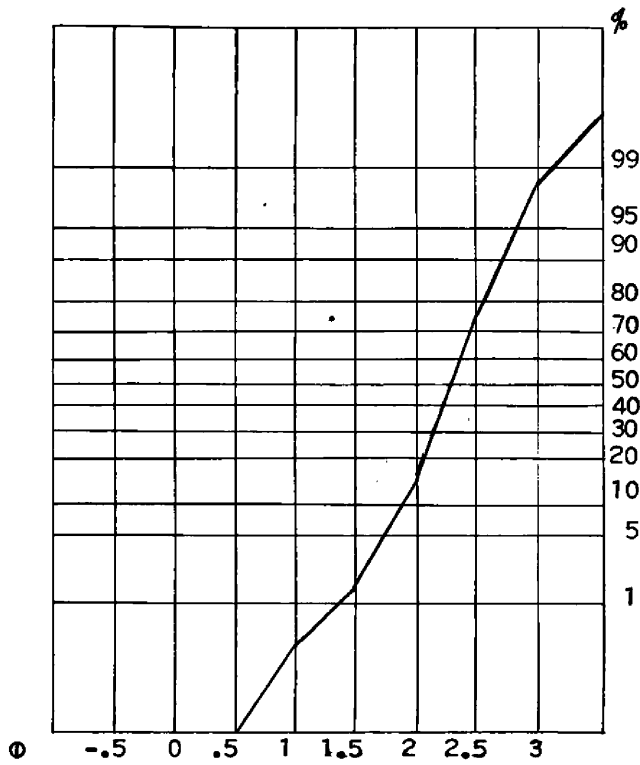


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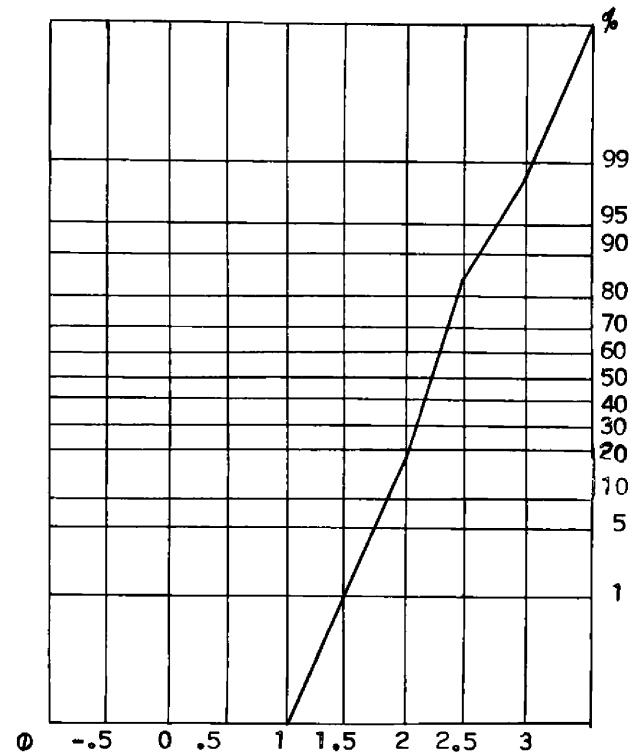


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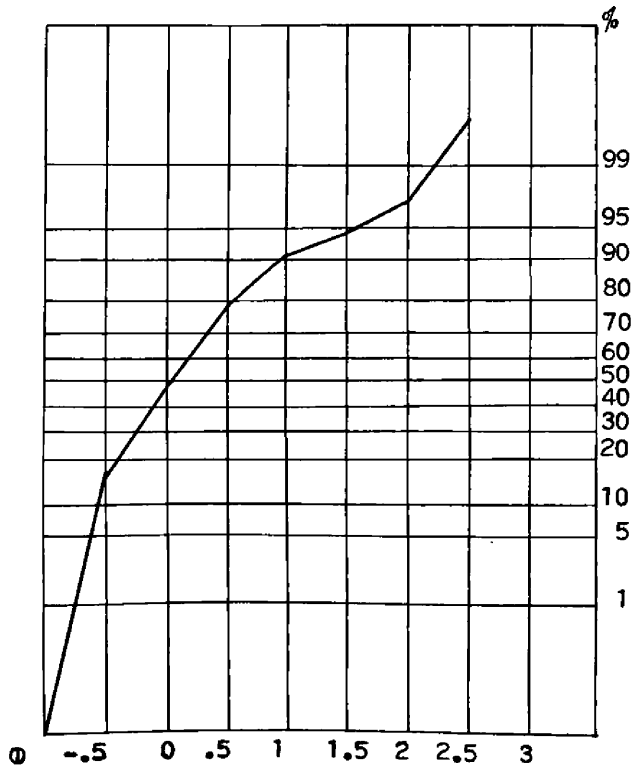
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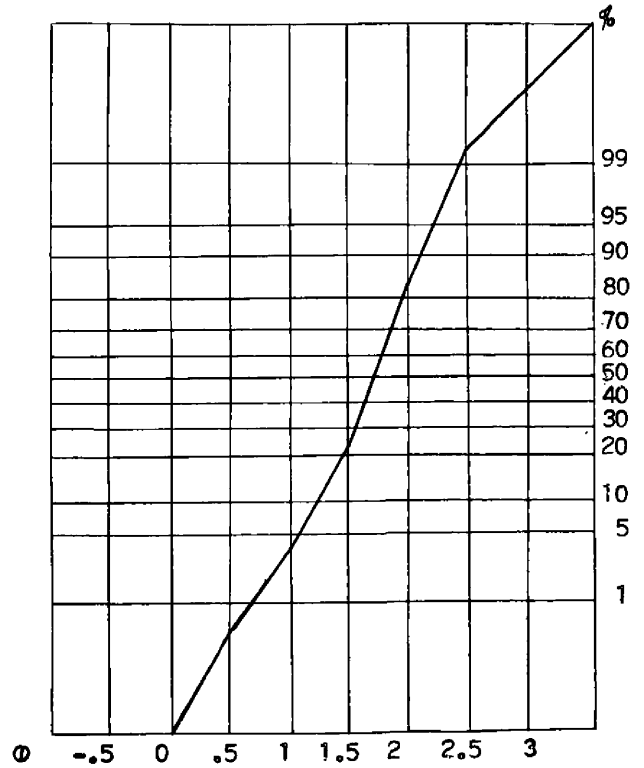
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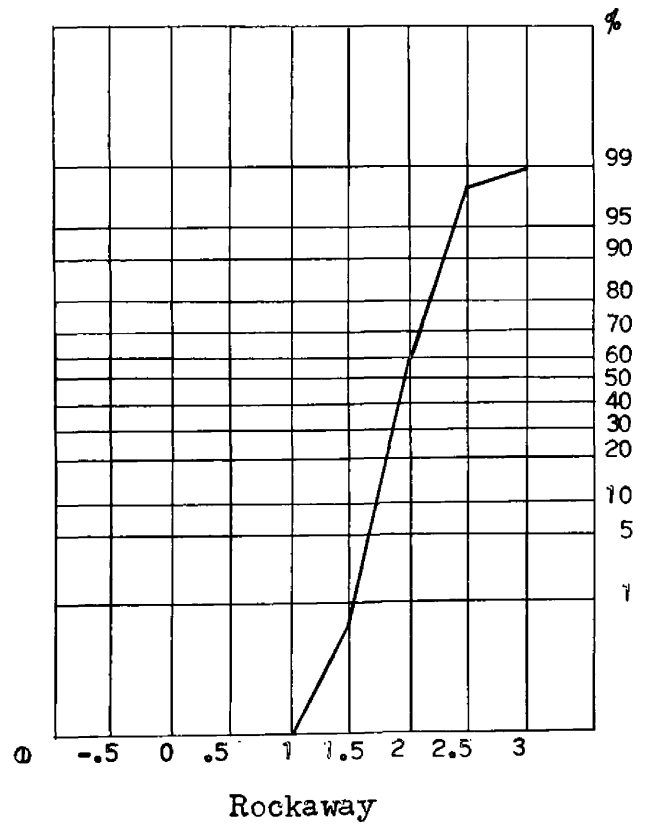
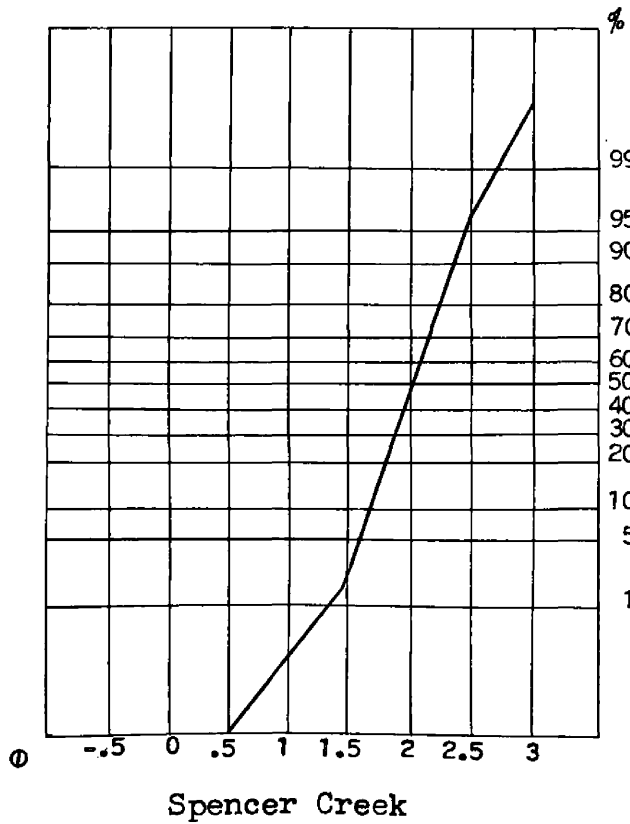
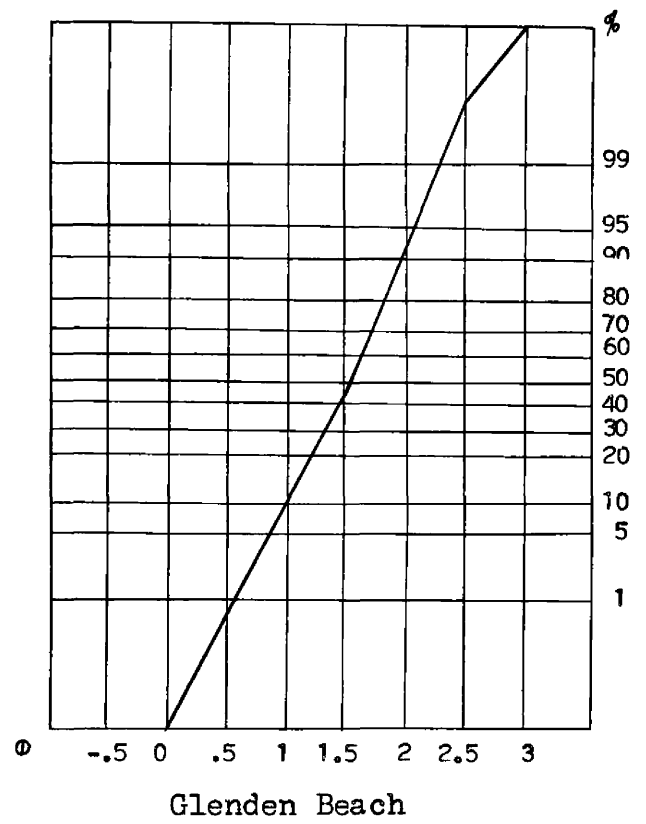
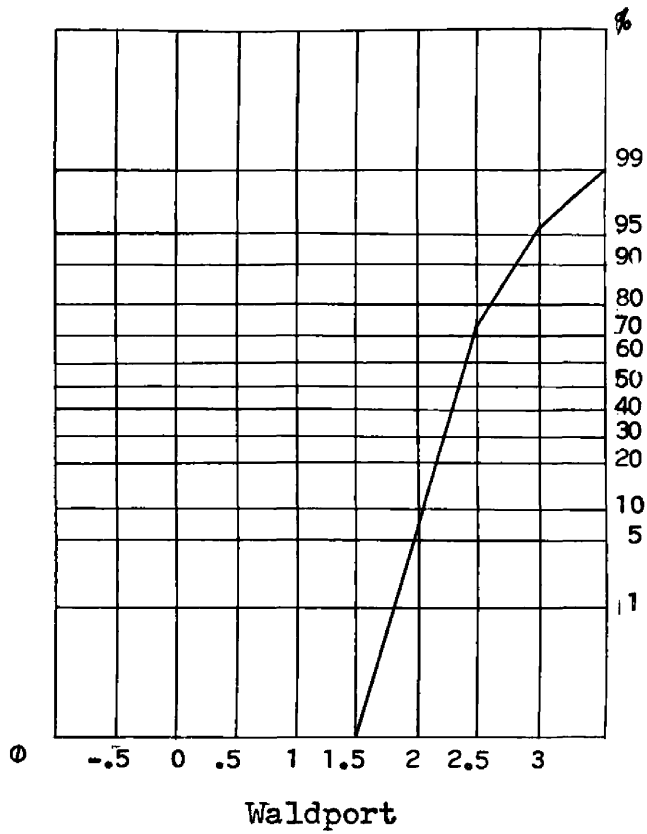


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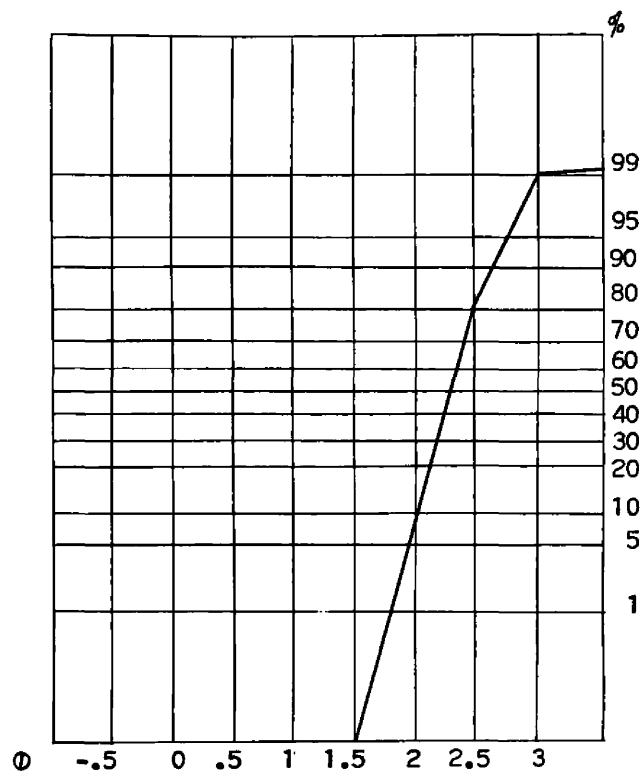


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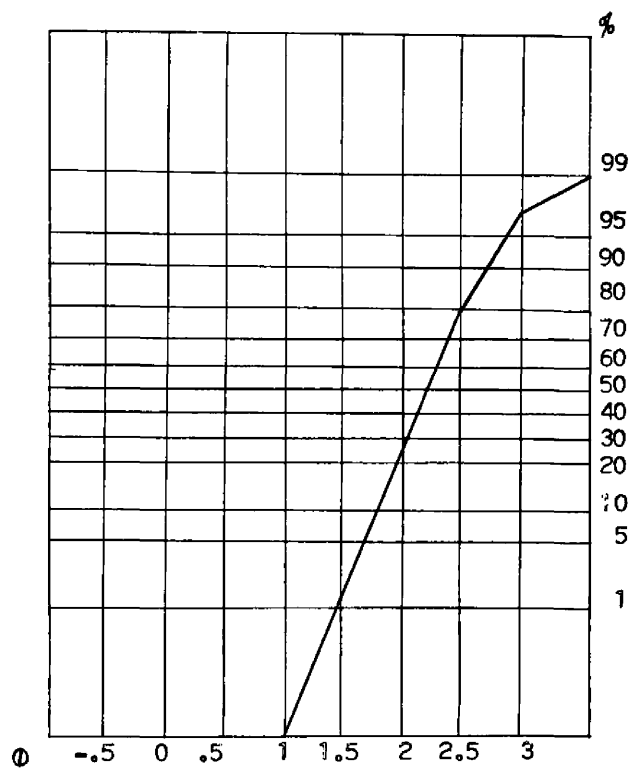
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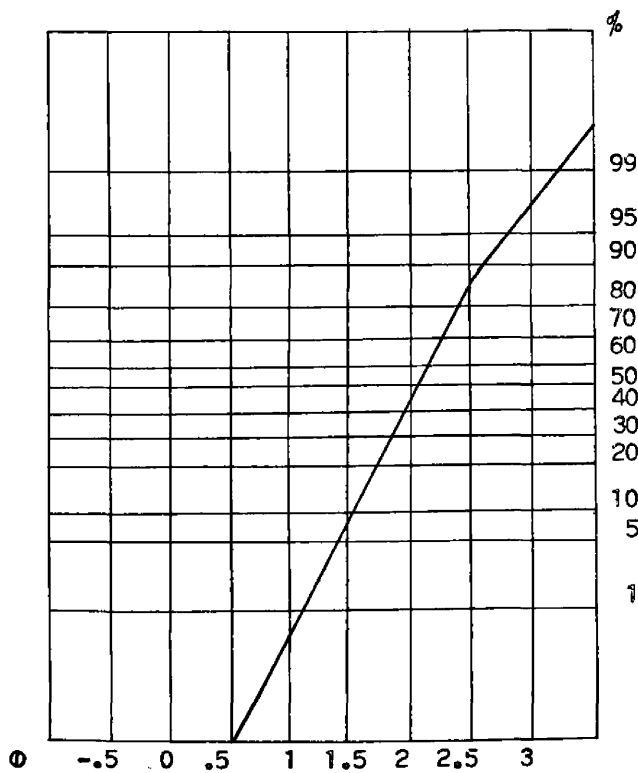
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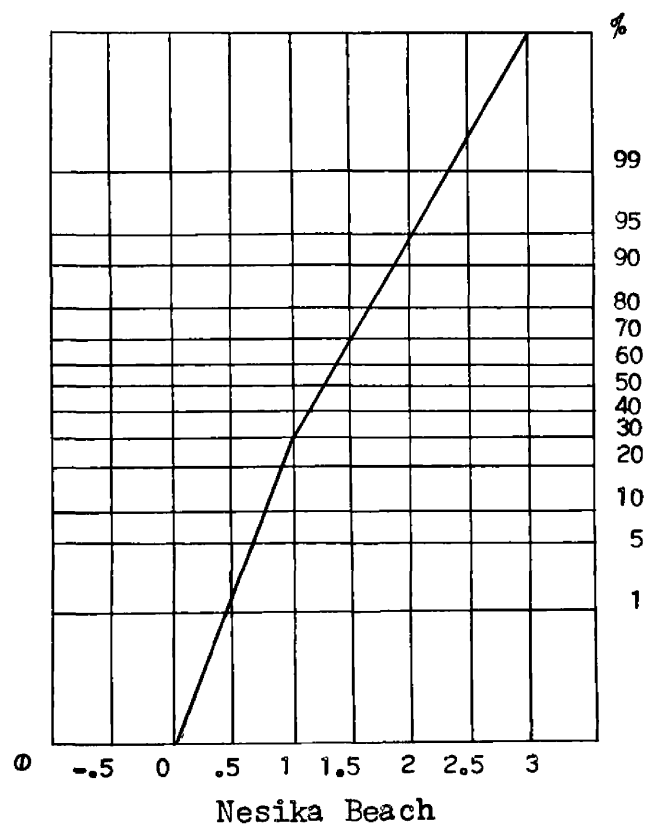
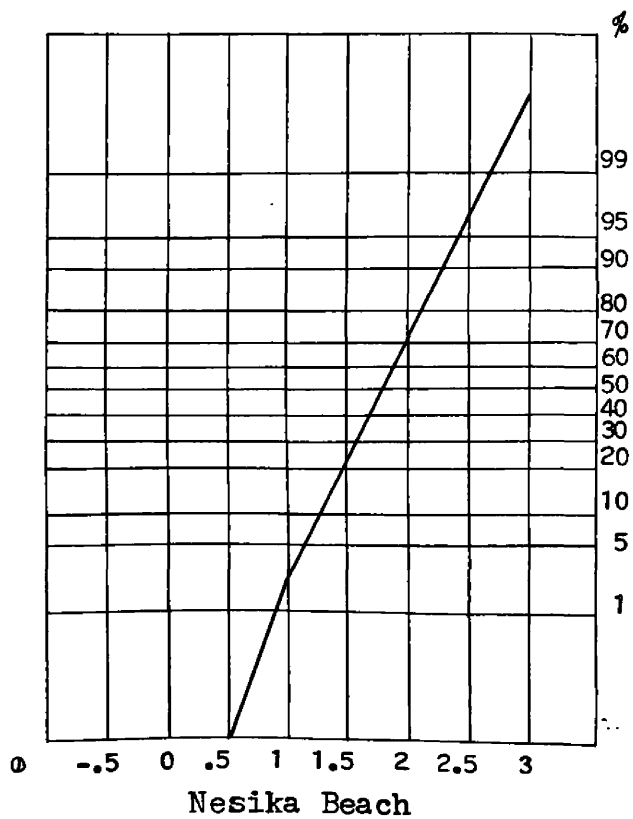
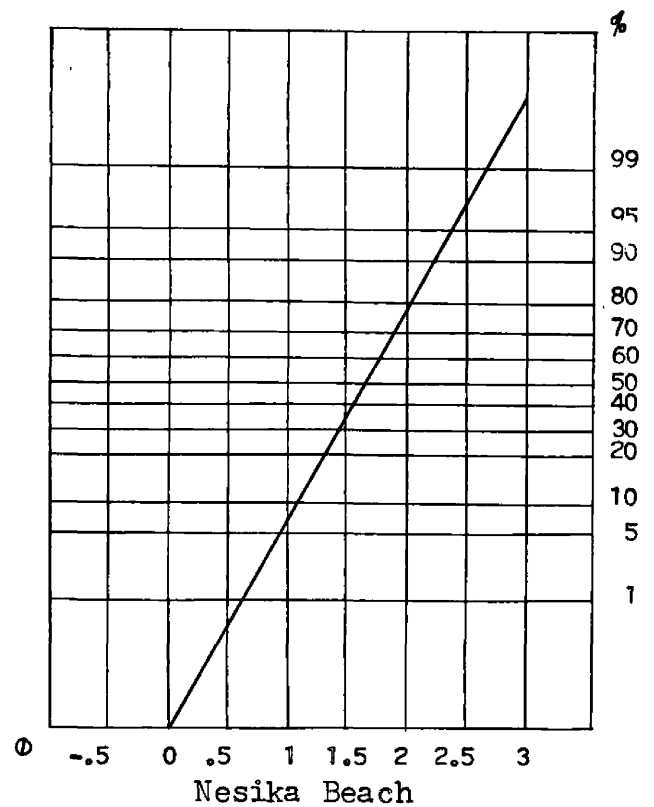
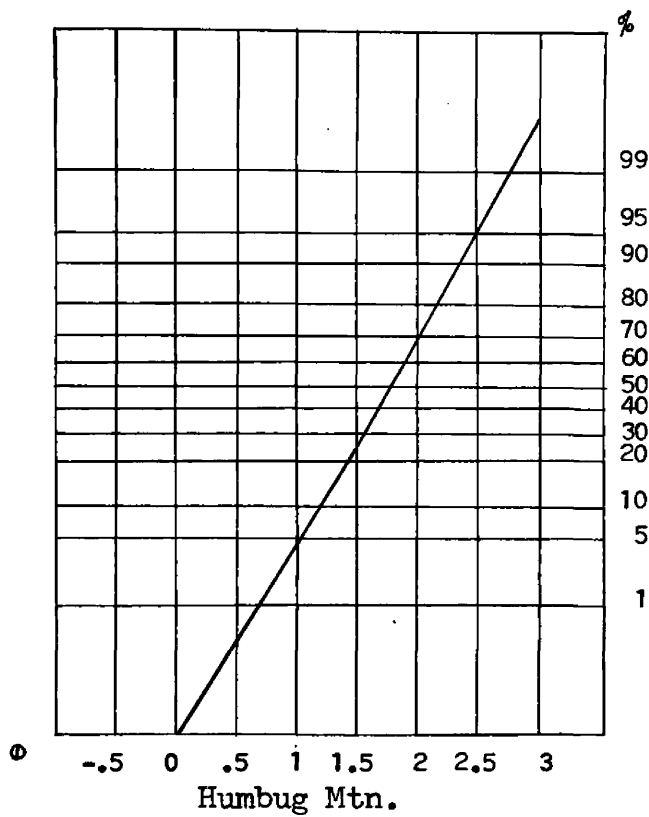


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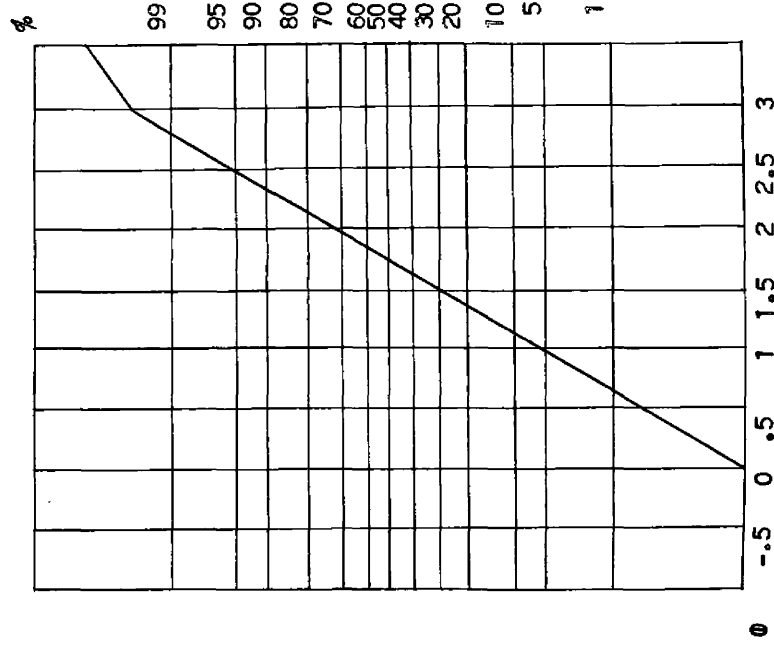
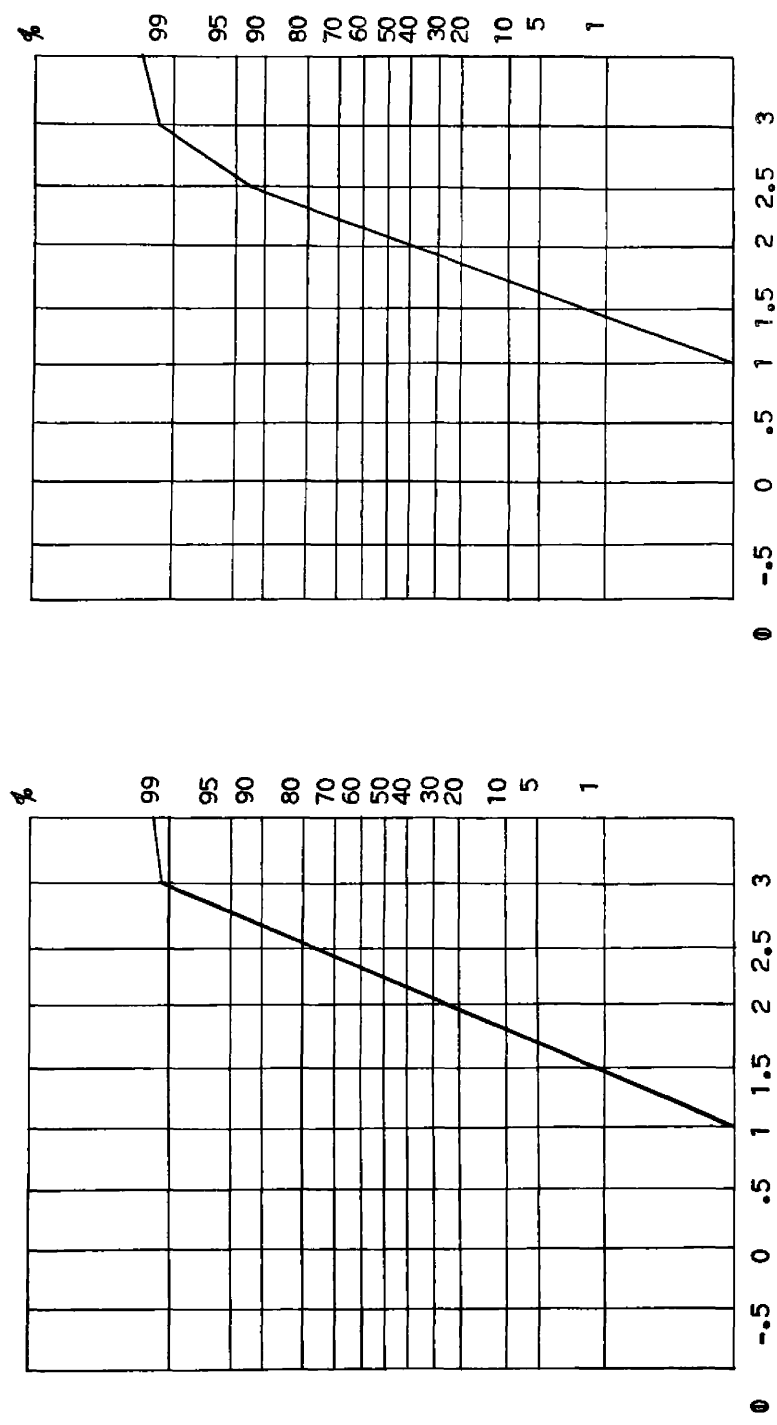
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DUNES



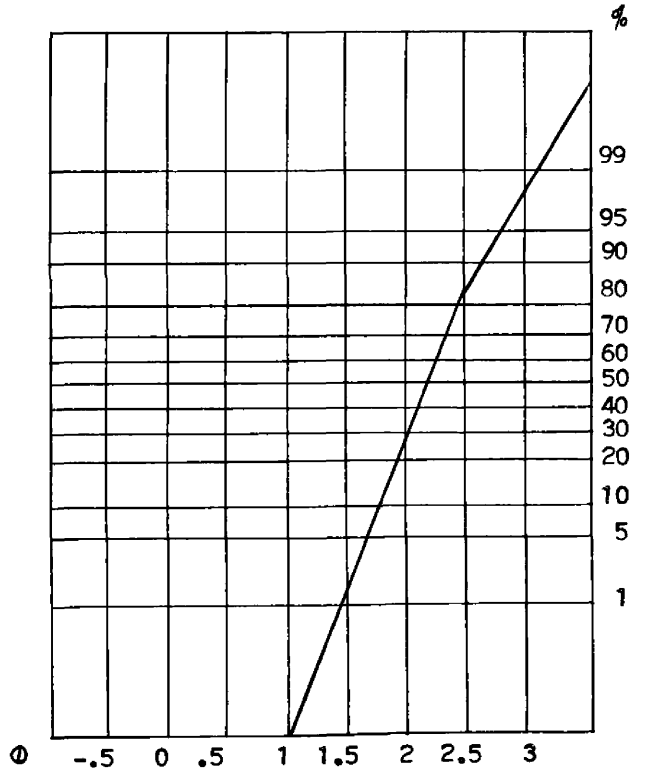
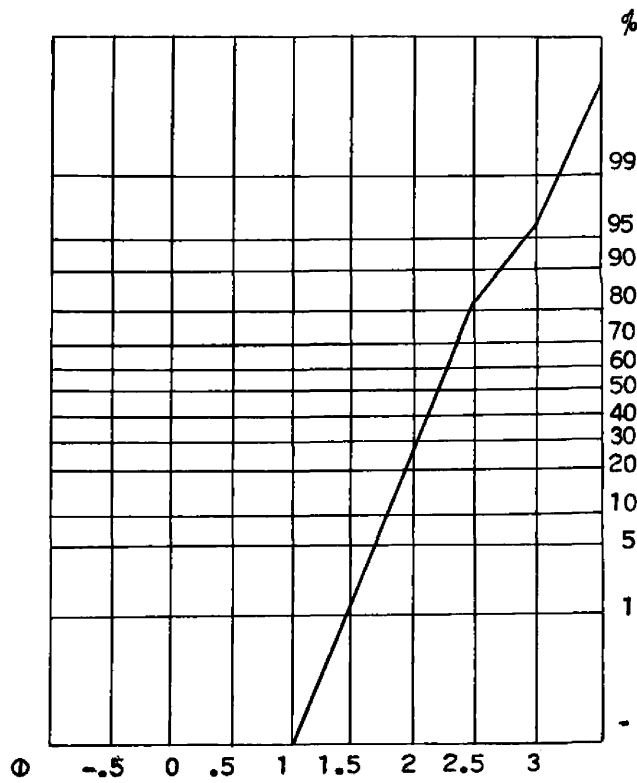
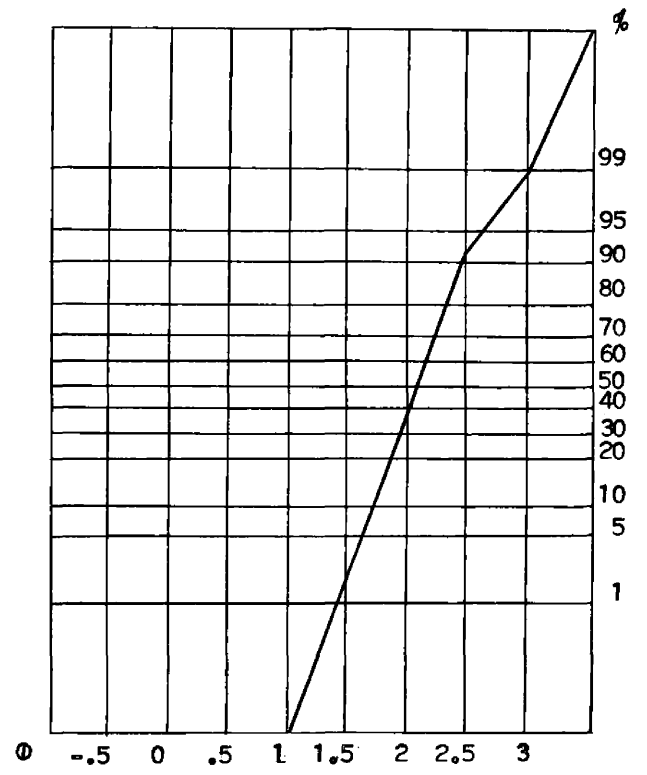
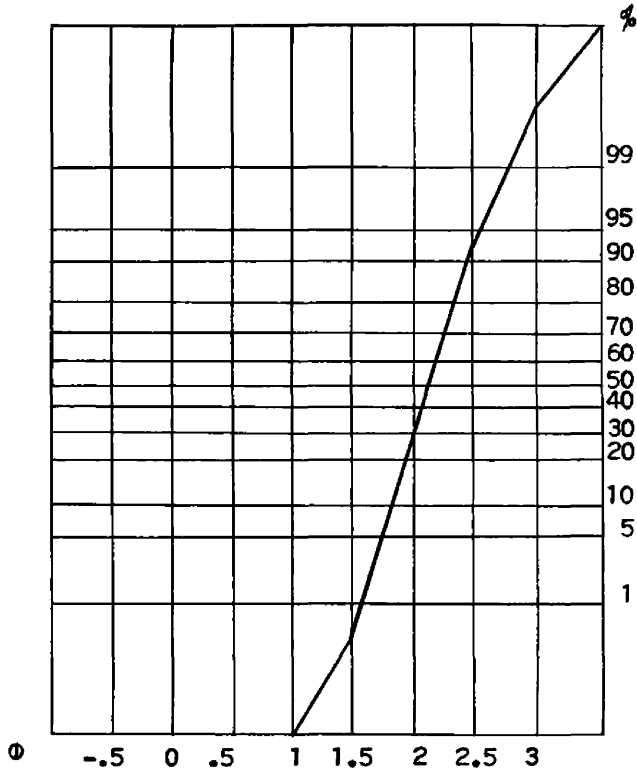
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Pistol River



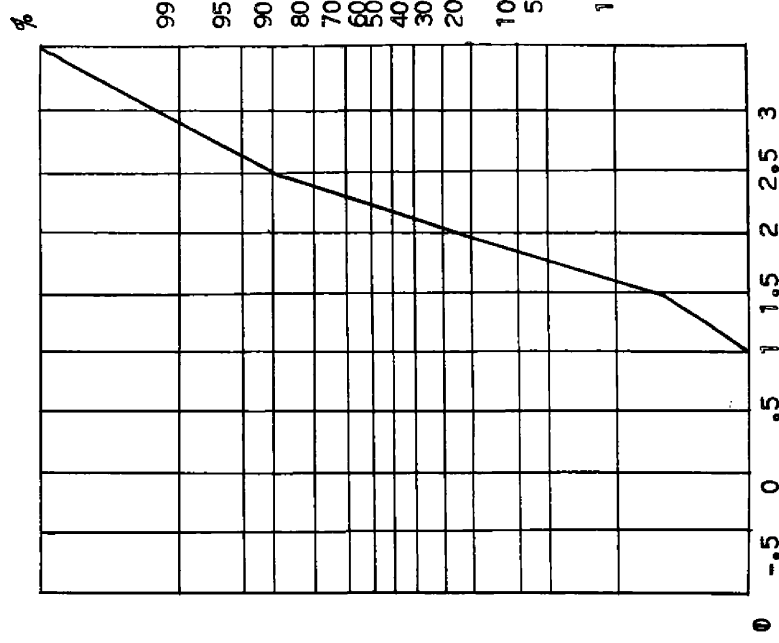
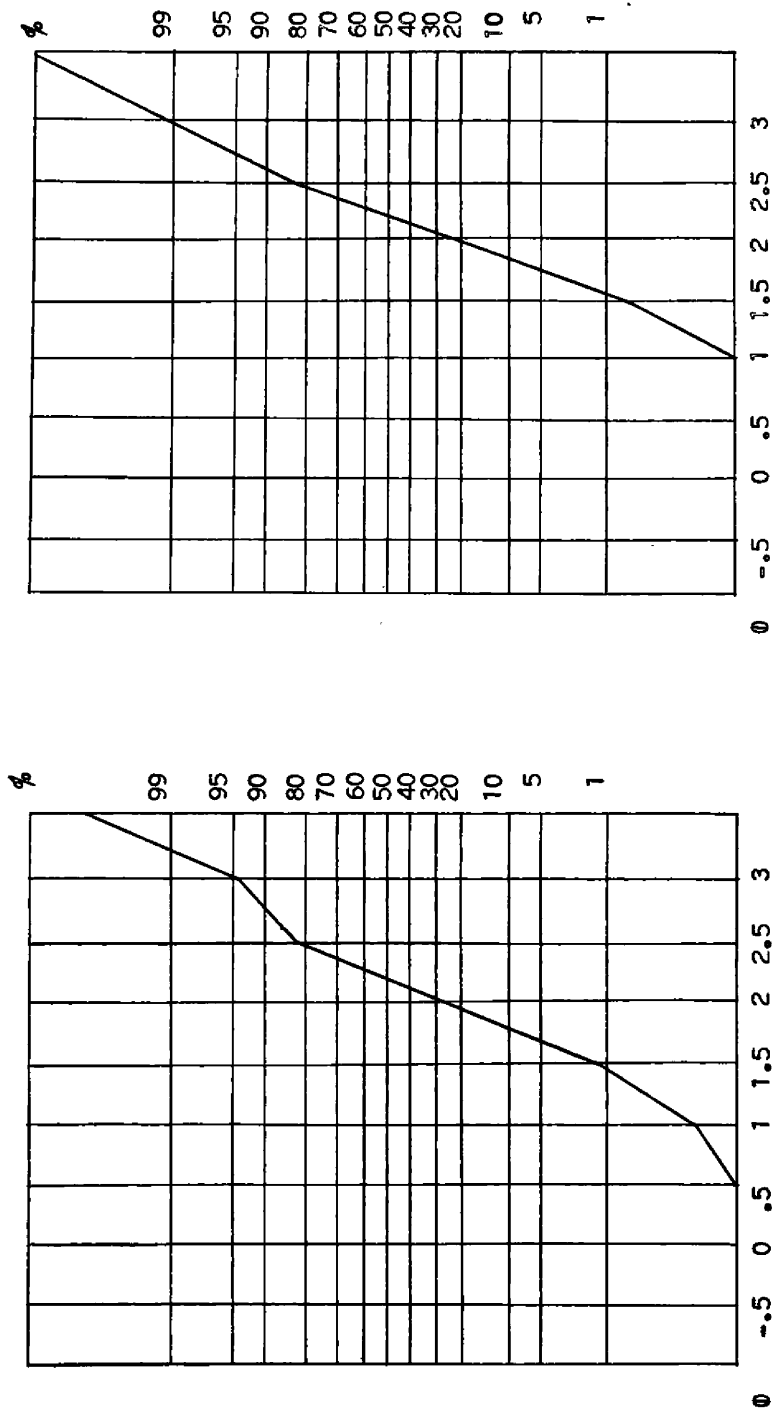
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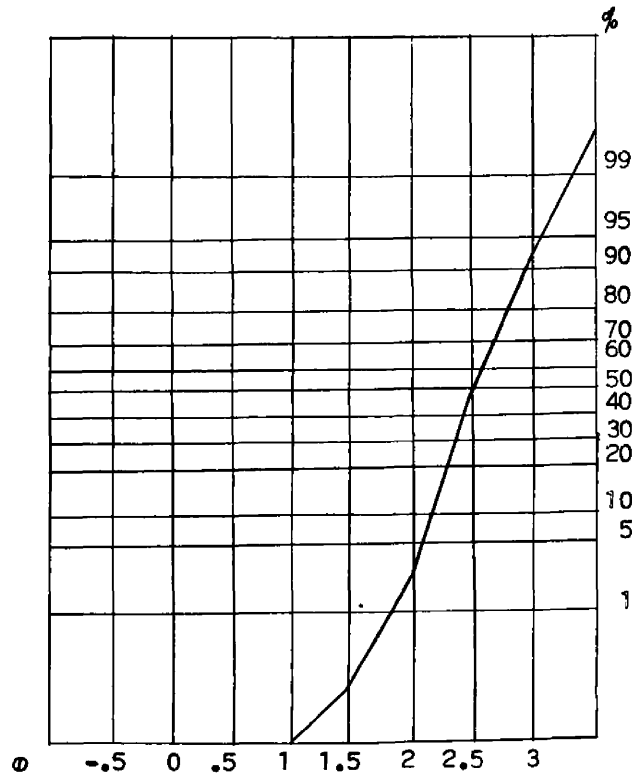
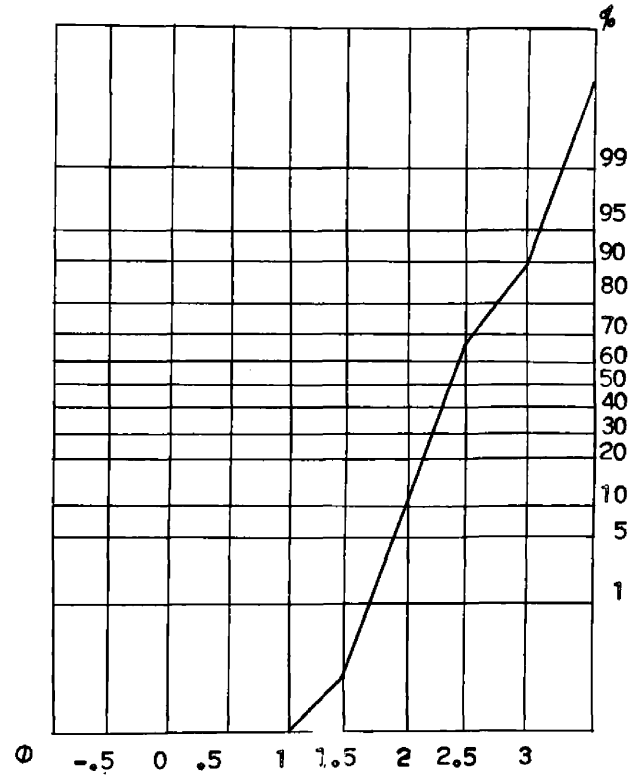
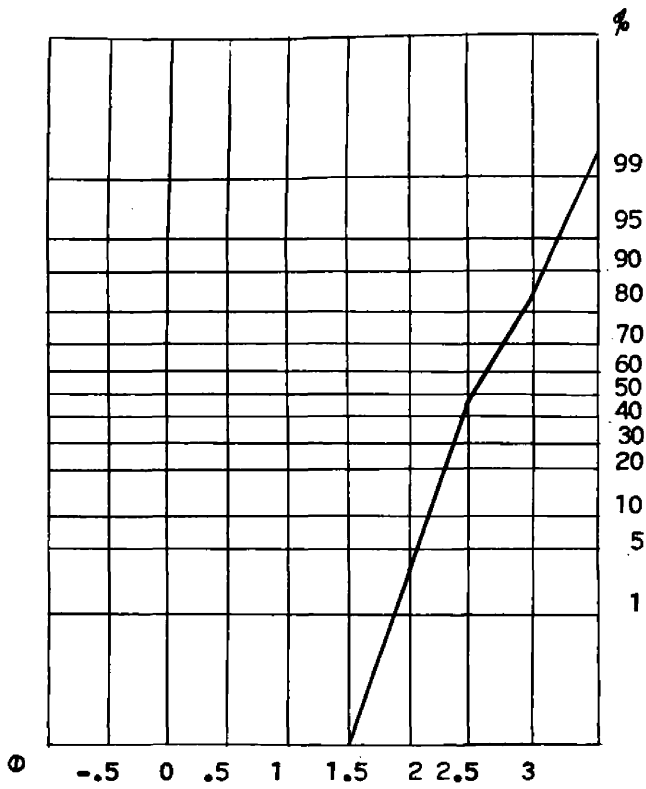
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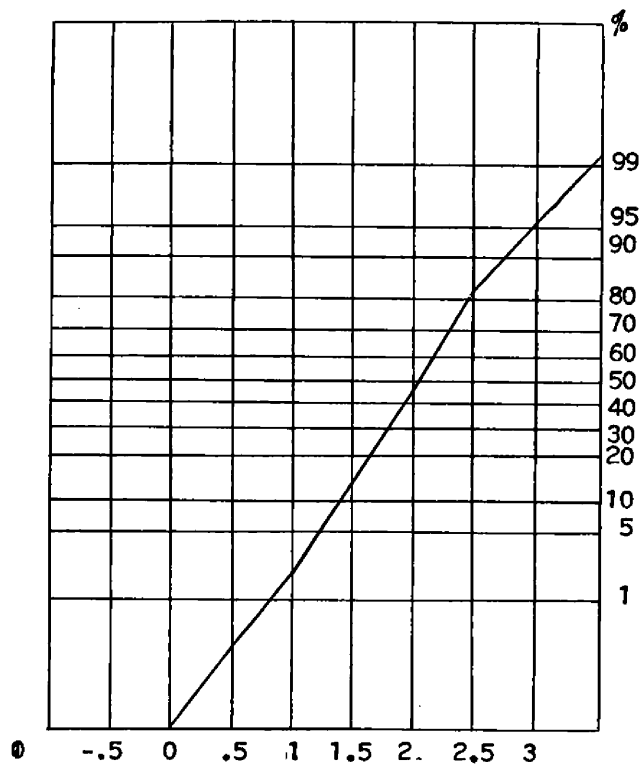


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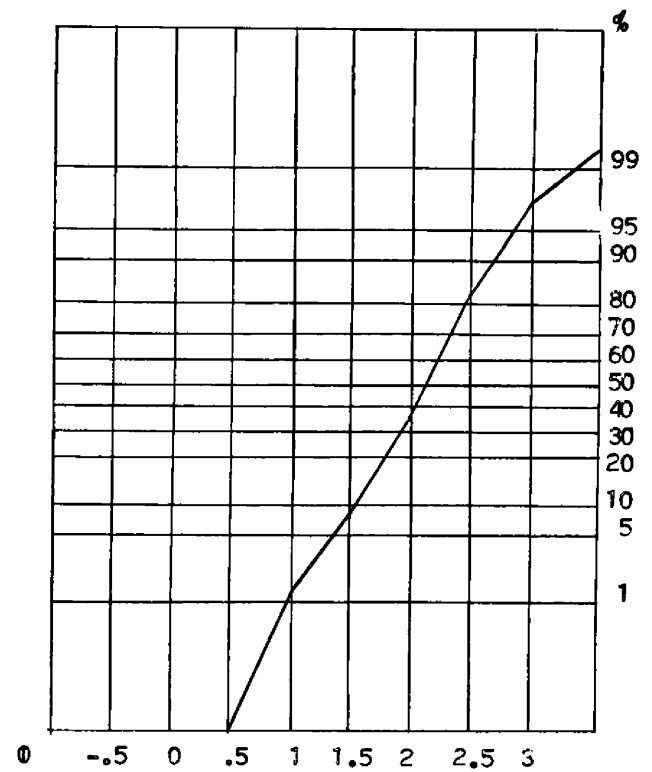
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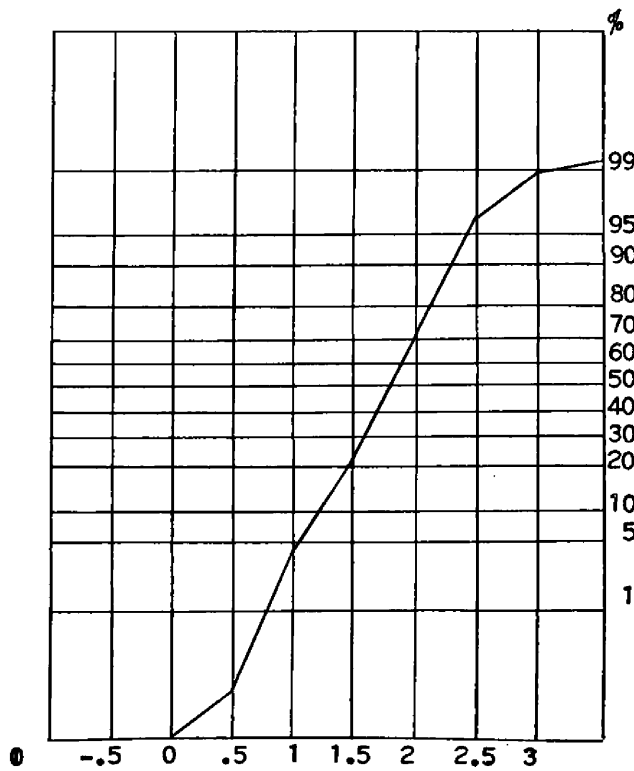
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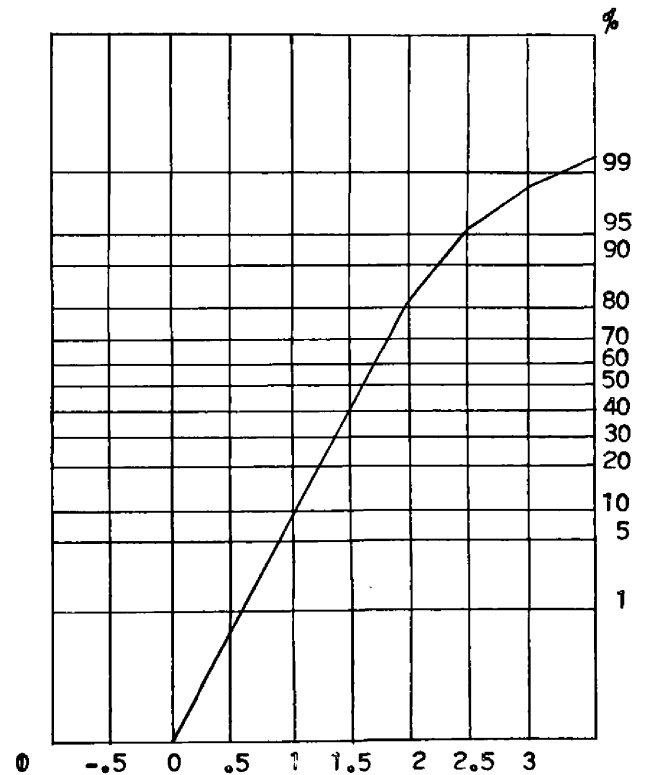
WHISKY RUN



WHISKY RUN



NELSCOTT



NELSCOTT